Journal

of

THE ROYAL AERONAUTICAL SOCIETY

JULY 1959

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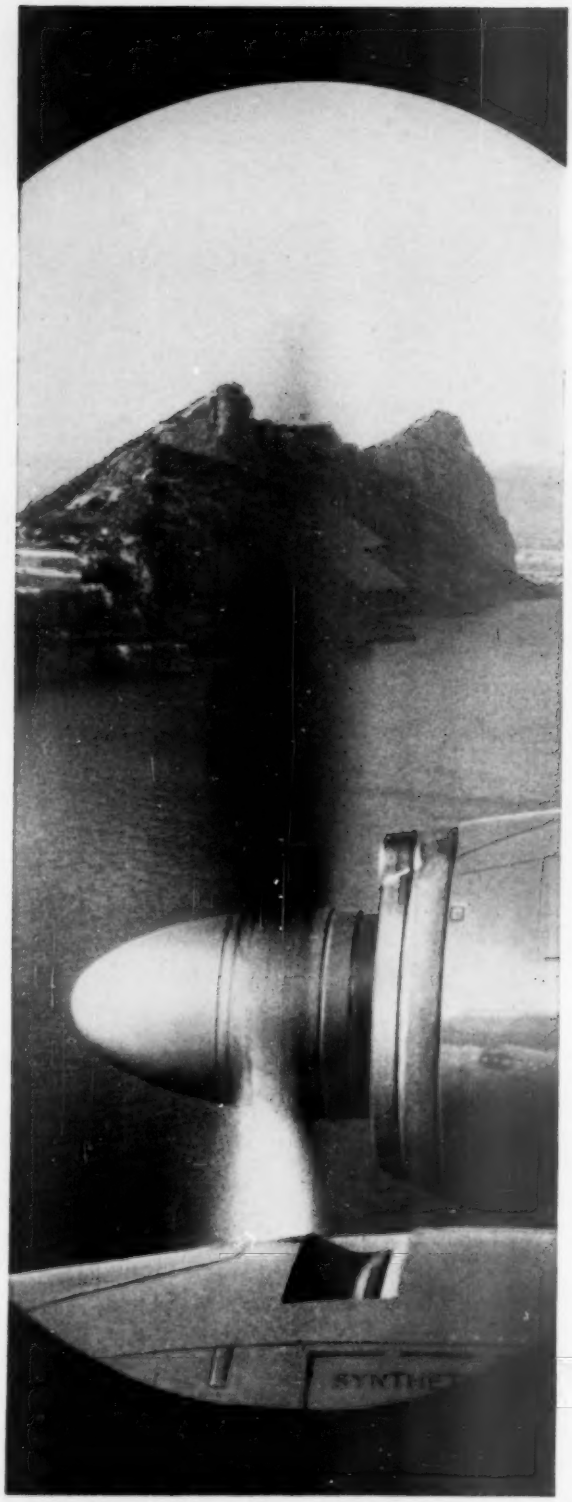

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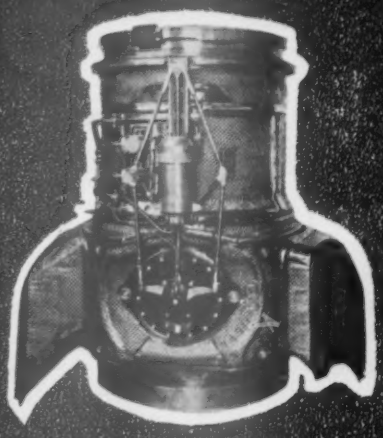

1

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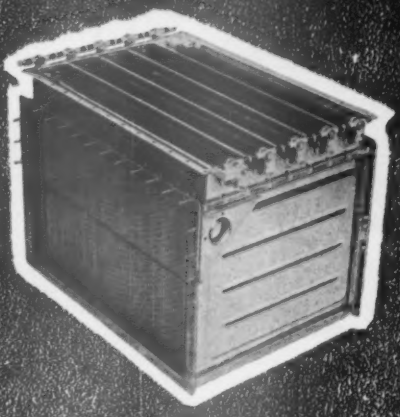

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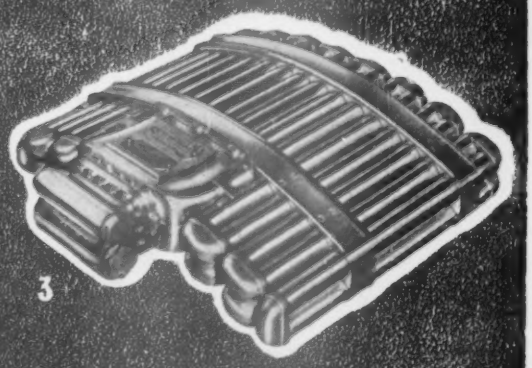

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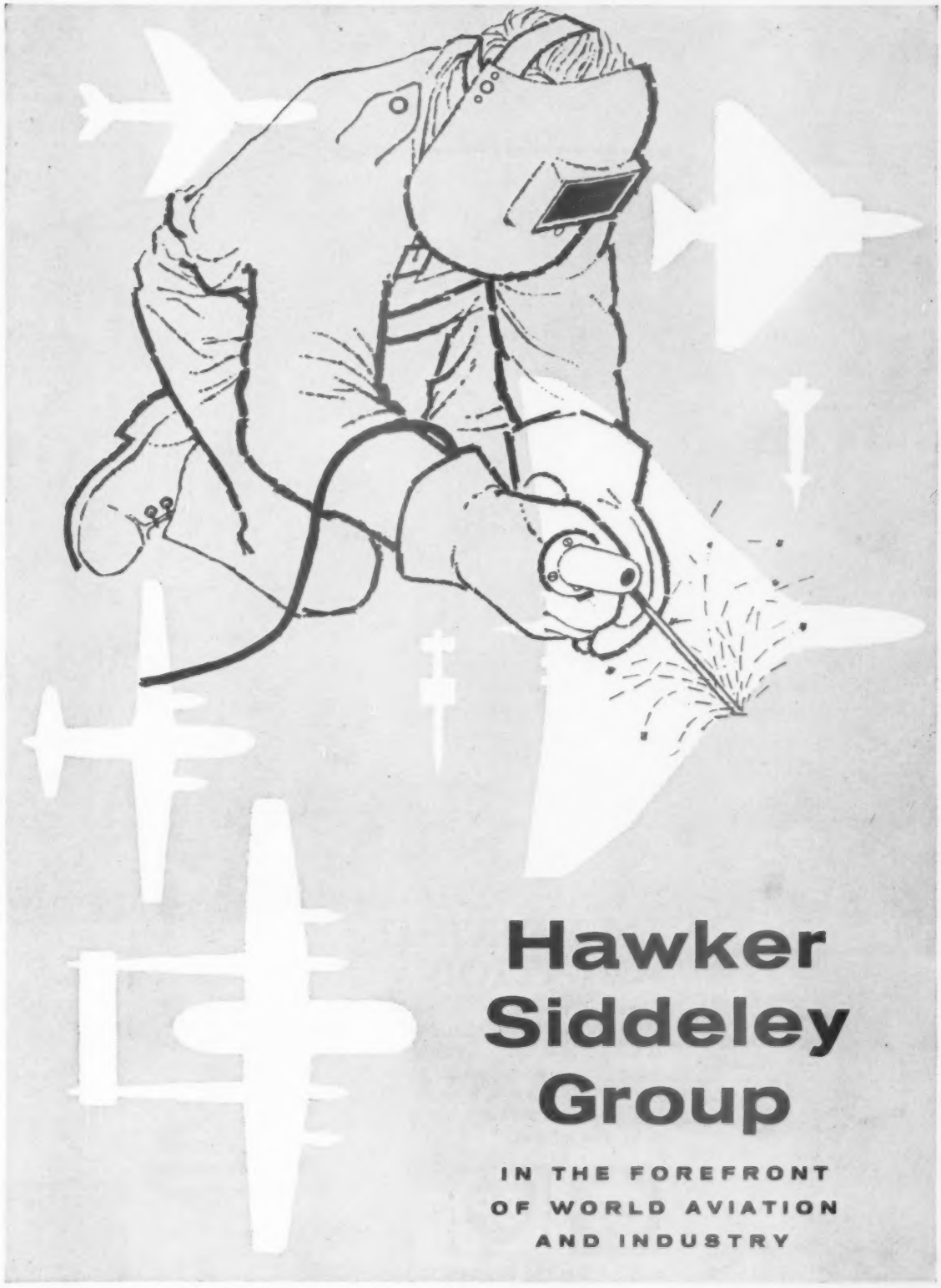
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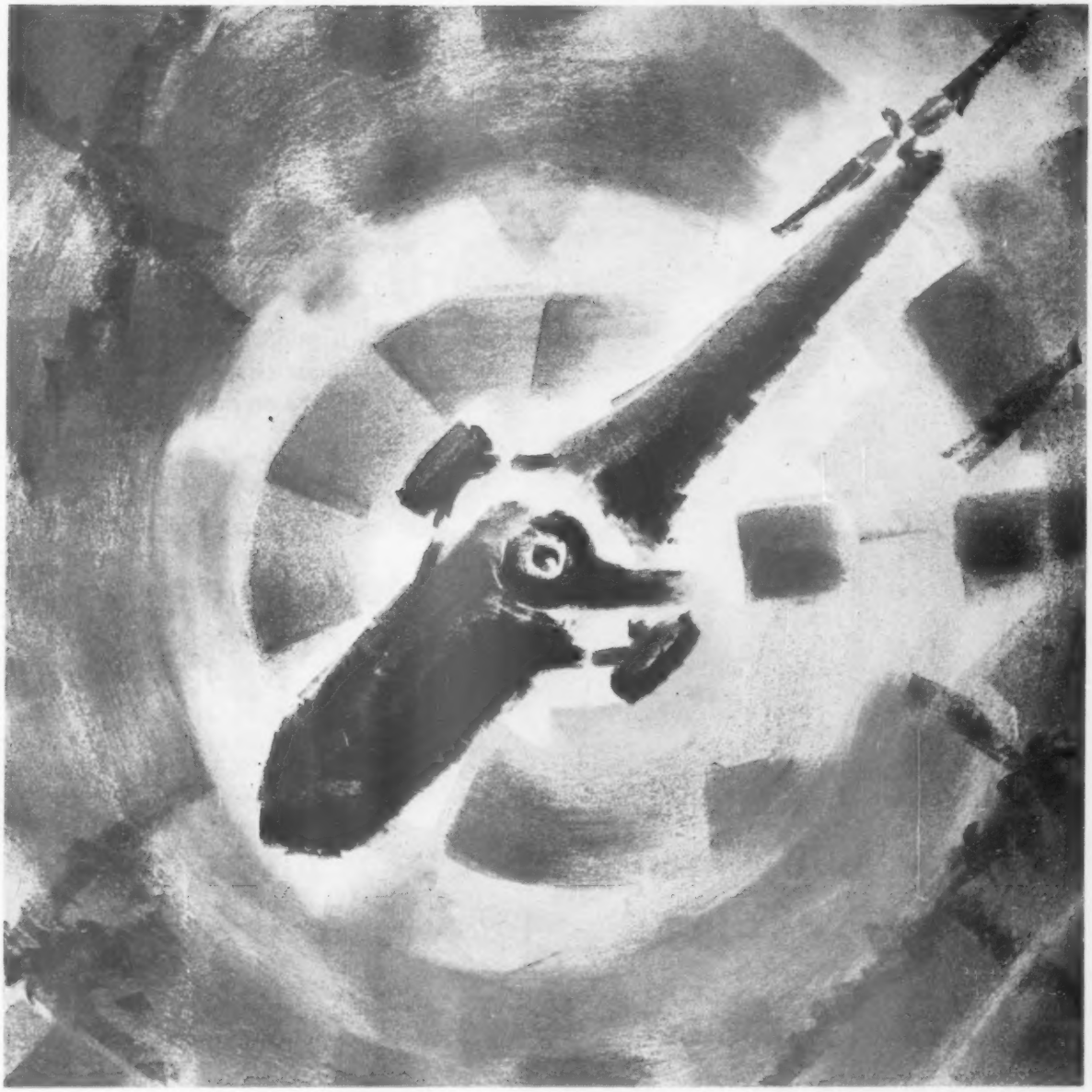

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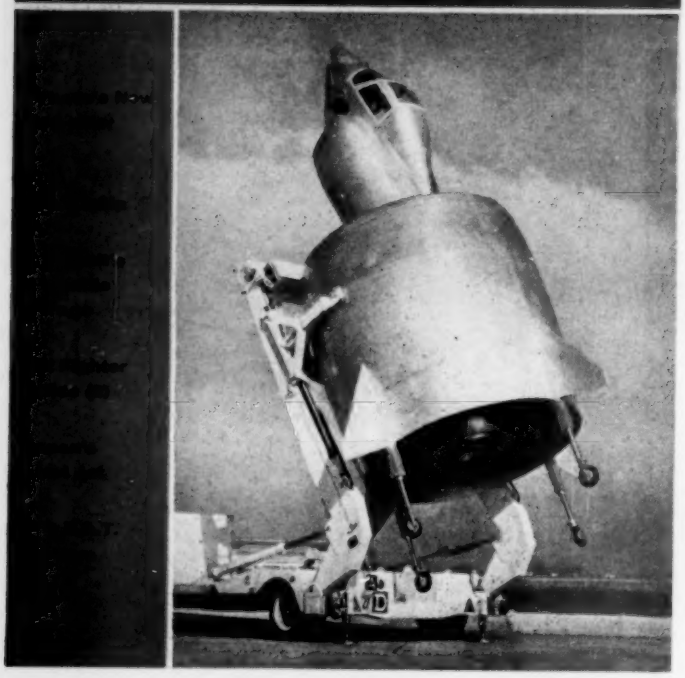

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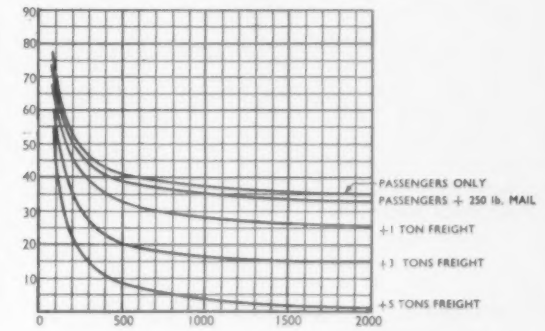

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Chairman: H. H. GARDNER, F.R.Ae.S.
Hon. Secretary: E. G. BARBER, A.F.R.Ae.S., Vickers-Armstrongs (Aircraft) Ltd., Weybridge.

YEOVIL
President: E. C. WHEELDON.
Chairmen: D. L. HOLLIS-WILLIAMS, F.R.Ae.S. and Dr. E. W. STILL, F.R.Ae.S.
Hon. Secretary: L. A. LANSDOWN, A.F.R.Ae.S., Westland Aircraft Ltd., Yeovil.

NOTICES

Agricultural Aviation Group

Council has agreed to the formation of an Agricultural Aviation Group within the Society. The aims of the Group are to further the use of aircraft in agriculture, forestry, pest control, fertilising, seeding, chemical application and similar subjects; and to provide facilities for those interested in such matters to meet and exchange ideas and information.

The formation of this Group was largely inspired by Mr. S. W. G. Foster, A.F.R.Ae.S., and a small Steering Committee. The Group expects to take an active part in the International Agricultural Aviation Conference which is to be held at Cranfield in September 1959.

The first meeting of the Agricultural Aviation Group will be a discussion evening on "Safety in Agricultural Aviation" to be held in the Library, 4 Hamilton Place on Friday, 17th July at 7.0 p.m. Two short papers will be presented:— "The Handling of Agricultural Chemicals," by Dr. E. F. Edson, M.Sc., M.B., Ch.B., Chief Medical Officer, Chesterford Park Research Centre, and "The Safety of Aircraft in Agricultural Work," by S. W. G. Foster, A.F.R.Ae.S.

The Agricultural Aviation Group is the second Group to be formed within the Society. The formation of the Man-Powered Aircraft Group was announced in the May Journal. The rules governing the formation of Groups were published in the December 1958 Journal (page XLV).

Members of the Society wishing to register with the Agricultural Aviation Group should inform the Secretary.

Vacation Course in Meteorology

A short vacation course in meteorology, arranged by the Joint Committee of the Field Studies Council and the Royal Meteorological Society, will be held at Malham Tarn Field Centre from 19th to 26th August 1959. The main emphasis will be on all practical aspects of meteorology and previous experience is not essential. The inclusive fee for the course is £8 18s. 6d.

Application forms and further particulars may be obtained from the Warden, Malham Tarn Field Centre, near Settle, Yorks.

Institut du Transport Aerien

Members may be interested to hear of the Institut du Transport Aerien of 4 rue de Solférino, Paris 7. There are two grades of membership with differing privileges and services and the interests of the Institut are in economics and other research applied to Air Transport. Samples of their publications may be seen in the Society's Library.

A.S.M.E. Transactions

For many years the Society's Library has been privileged to receive, as a "depository library" (one of the few in this country) the bound volumes of the Transactions of the American Society of Mechanical Engineers. Although the list of those to be so privileged has now had to be revised and curtailed by the A.S.M.E. the Society will continue to receive the Transactions and the "run" will thus be uninterrupted. Because of their value the Transactions are available for reference only. The Council wishes to thank the American Society of Mechanical Engineers for their courtesy.

Associate Fellowship Examinations December 1959

The closing date for Candidates in the United Kingdom for December 1959 Examinations is 31st August. Entry forms may be obtained from the Secretary. The closing date for entries outside the United Kingdom was 30th June.

General Meeting, 4th May 1959—By-Laws

At a General Meeting of Members held on 4th May 1959, the proposed amendments to the By-Laws were approved by the meeting with the exception of an amendment to Rule 6 on Subscriptions. The amendment proposed, and accepted, is as follows:—

"The annual subscriptions, transfer and entrance fees, registration fees, and life composition fees payable by members, shall be those proposed by the Council at a General Meeting, amended if thought fit by a two-thirds majority of the voters present at that meeting, and approved by a simple majority of the voters in a postal ballot. They shall not exceed those listed in the Appendix.

"The annual subscriptions for certain classes of members may be varied according to their place of residence, but any such variation must be approved by the same procedure as just described. For the purpose of this classification the place of residence of a member in any year shall be his registered address on the first day of January of that year. All annual subscriptions are due on the first day of January for the year then beginning."

The new By-Laws are now before the Privy Council.

Paris Aero Show—1959

Mr. P. G. Masefield, the President, together with the President-Elect, the Past President and members of Council were among the guests present at a memorable dinner given by M. Marcel Dassault at his home in Paris. This was the first opportunity the Council had of meeting M. Dassault since he was awarded the Society's Gold Medal in May 1959 when General Gallois received the Medal in London on his behalf. The President expressed the thanks of the British guests in French.

Holidays in France

A list of members of A.F.I.T.A. who wish to exchange holidays with their children and children of members of the Society is now available and can be had on application to the Secretary.

Acknowledgment

The Council wish to thank Mr. I. W. C. Robertson (*Associate Fellow*) for presenting back numbers of the "Journal of the Helicopter Association of Great Britain."

August Bank Holiday

The Library and Offices of the Society will be closed from Friday afternoon 31st July until 9 a.m. on Tuesday 4th August.

Honours Awarded to Members

The Council of the City and Guilds of London Institute have conferred the Fellowship of the Institute (F.C.G.I.) on the following Members of the Society in recognition of their distinguished contributions to Industry:— Paul Adorian (*Associate Fellow*), Leslie Giddens Brazier (*Associate Fellow*).

Honorary Fellowship of the City and Guilds Institute has been conferred on Professor O. A. Saunders (*Fellow*).

Bristol University Honorary Degree

Dr. Barnes N. Wallis (*Fellow*), has been awarded the Honorary Degree of Doctor of Science in Engineering of Bristol University.

The Journal

We regret that the dispute in the printing industry has inevitably delayed the production of this issue and has also resulted in its being reduced in size.

LECTURE THEATRE APPEAL

The Society has been honoured by a donation from H.R.H. The Duke of Edinburgh, *Honorary Fellow*, whose interest and support are greatly appreciated.

In general, the response to the Appeal has been quite encouraging, but it is felt that there must be many members who, although they fully intend to make a donation, have put off doing so for one reason or another. The time is approaching when an accurate figure of the ultimate sum subscribed will be required so that the building contracts may be placed. Members are therefore asked to send in their donations as soon as possible.

A first list of subscribers was published in the June Journal and the following list shows further donations received up to the time of going to press.

Donations	£	s.	d.	£	s.	d.
Previous total (including minor adjustments)	923	10	4			
Sqn. Ldr. F. Allsopp	2	0	0			
E. L. Bass, Esq.	8	0	0			
J. W. Bateman, Esq.	4	4	0			
Birmingham Branch	18	8	0			
Boscombe Down Branch ..	26	0	0			
Mrs. J. Bradbrooke	3	3	0			
British Aviation Insurance Co. Ltd.	200	0	0			
British Oxygen Co. Ltd. ..	25	0	0			
Brough Branch	50	0	0			
T. M. Carsen, Esq. (Can. $10.00)	3	0	0			
H. K. Cartwright, Esq. ..	10	0	0			
E. J. Catchpole, Esq.	5	5	0			
Christchurch Branch	20	0	0			
Flt. Lt. R. A. Cunningham ..	7	0	0			
M. J. Dean, Esq.	1	1	0			
C. Dykes, Esq.	10	10	0			
Elliott Bros. (London) Ltd. ..	105	0	0			
D. G. Elms, Esq.	3	0	0			
A. H. Emden, Esq.	3	0	0			
'Flight' Magazine	52	10	0			
Sqn. Ldr. G. G. Fowler ..	5	5	0			
Air Vice-Marshal H. P. Fraser	15	0	0			
S. Gray, Esq.	5	0	0			
Dr. J. J. Green (U.S. $25.00)	8	15	0			
J. D. Haddon, Esq.	5	0	0			
J. M. Hahn, Esq.	2	2	0			
A. B. Haines, Esq.	3	0	0			
G. W. Hall, Esq.	5	5	0			
W. J. Halland, Esq.	5	0	0			
E. S. Harris, Esq.	10	10	0			
Cdr. S. C. Haynes	5	5	0			
Hendrey Relays Ltd.	10	10	0			
A. S. Hickerton, Esq. ..	3	3	0			
A. J. Hughes, Esq.	8	0	0			
Sqn. Ldr. O. L. Hyde	2	0	0			
Indonesian Embassy	10	0	0			
Cdr. W. S. Jerome	2	2	0			
Flt. Ltd. E. E. Judkins ..	17	10	0			
Capt. E. Keith-Davies ..	10	0	0			
A. Knight, Esq.	1	1	0			
Air Cdre. D. W. Lane ..	2	2	0			
P. Laws, Esq.	2	10	0			
R. E. Le Long, Esq.	10	0	0			
J. D. Ledger, Esq.	1	10	0			
Leslie and Godwin Ltd. ..	250	0	0			
M. Lewin, Esq.	2	2	0			
Model Aeronautical Press Ltd.	10	10	0			
Sqn. Ldr. W. Muirhead ..	7	10	0			
Newton Bros. (Derby) Ltd. ..	52	10	0			
Northern Aluminium Co. Ltd.	100	0	0			
Gp. Capt. F. A. Norton ..	2	2	0			
Park, Ward and Co. Ltd. ..	2	2	0			
W. Pitson, Esq.	10	0	0			
Power Jets (Research and Development) Ltd.	100	0	0			
Pressed Steel Co. Ltd. ..	50	0	0			
C. G. Pullin, Esq.	3	3	0			
R.A.F. Swanton Morley ..	5	5	0			
Carried forward	2206	15	4			

	£	s.	d.	£	s.	d.
Brought forward	2206	15	4			
Lt. R. H. M. Richardson-Bunbury	2	10	0			
Sqn. Ldr. H. H. Ricketts ..	5	0	0			
Rush and Tompkins Ltd. ..	50	0	0			
M. Salisbury, Esq.	6	6	0			
J. W. Schofield, Esq.	5	0	0			
Flt. Lt. D. E. Sharpe	1	0	0			
Stewart, Smith and Co. Ltd. ..	40	16	3			
Stricklands and Co. (Blackfriars) Ltd.	5	5	0			
A. Swan, Esq.	5	5	0			
G. W. Taylor, Esq.	3	0	0			
Temple Press Ltd.	26	5	0			
Flt. Lt. A. B. Thompson ..	1	0	0			
Tiltman, Langley Ltd. ..	5	5	0			
Ing. S. Tomasino	5	0	0			
W. J. Trotman, Esq. (U.S. $10.00)	3	11	6			
R. C. Turner, Esq.	2	0	0			
Sqn. Ldr. A. D. Weir	6	6	0			
Sqn. Ldr. R. G. Welcomme ..	2	0	0			
Dr. E. W. C. Wilkins	25	0	0			
G. H. Williams, Esq.	1	0	0			
E. G. A. Wilton, Esq. ..	5	5	0			
T. P. Wright, Esq.	40	0	0			
Wright-Anderson (Clean Homes Service) Ltd. ..	10	10	0			
R. Yorke, Esq.	5	0	0			
				2469	0	1

7-year Covenants	£	s.	d.
	p.a.		
Previous total (including minor adjustments) ..	364	18	6
Sqn. Ldr. B. S. E. Beattie ..	2	0	0
Flt. Lt. D. Biltcliffe	1	1	0
C. T. Bowring and Co. Ltd. ..	10	10	0
K. F. Brading, Esq.	1	0	0
*Bristol Aircraft Ltd. ..	714	5	9
W. K. Campe, Esq.	1	0	0
H. L. Cox, Esq.	3	3	0
Sir Harold Roxbee Cox ..	10	0	0
S. D. Davies, Esq.	5	0	0
E. M. Dowlen, Esq.	2	0	0
Sir Roy Fedden	30	0	0
L. F .Fox, Esq.	2	0	0
Cdr. B. W. Galpin	3	0	0
S. B. Gates, Esq.	3	0	0
E. J. Gregson, Esq.	1	1	0
K. D. Harris, Esq.	2	0	0
R. Hills, Esq.	1	10	0
Flt. Lt. J. N. Hullah	1	0	0
G. Jackson, Esq.	1	0	0
Sir B. Melvill Jones	3	0	0
F. A. Kerry, Esq.	1	1	0
Air Cdre. D. F. Lucking ..		10	0
R. B. Marsh, Esq.	1	0	0
R. E. Penney, Esq.	1	1	0
Flt. Lt. E. Rhoades	1	0	0
J. V. Roberts, Esq.	2	2	0
V. A. B. Rogers, Esq. ..	1	0	0
Flt. Lt. R. G. Rowe	1	1	0
Carried forward	1171	4	3

**In the Stop Press note in the June* JOURNAL *the deed of Covenant received from Bristol Aircraft Ltd. was expected to produce £5,000 over a period of seven years, but this sum made no provision for recovery of income tax: Bristol Aircraft's donation will, in fact, produce about £8000*

	£ s. d. p.a.		
Brought forward	1171	4	3
B. S. Shenstone, Esq.	5	0	0
F. Smith, Esq.	1	0	0
A. G. Strawford, Esq. ..	1	0	0
A. W. Thompson, Esq. ..	1	11	6
R. H. Thring, Esq.	4	0	0
Air Cdre. Sir Frank Whittle ..	5	0	0
Sqn. Ldr. D. L. Wood ..	1	0	0
			*1189 15 9

**With Income Tax at the present standard rate of 7/9 in the £, this figure should produce £13600 (approx.) over the 7-year period.*

Bankers' Orders for an Unspecified Number of Payments	£ s. d.		
Previous total	18	1	0
D. Gilbert, Esq.	3	0	0
H. J. Jauncey, Esq.	5	5	0
A. A. B. Naylor, Esq. ..	5	0	0
Pergamon Press Ltd.	10	10	0
			41 16 0
			£3720 11 10

Elections

The following is a list of new members and transfers of membership of the Society:—

Associate Fellows

Stanley Michael Baldwin (*from Graduate*)
Malcolm Hesketh Barratt (*from Graduate*)
Anthony Lionel Blackman (*from Graduate*)
Robert William McGregor Boswell
Derek George Brooks (*from Graduate*)
Lloyd Edgar Buley
Tynan Gerard Campbell-Burns
David Dunlop Ewart (*from Graduate*)
Richard James Crosby Farrell
Maurice Massey Gates (*from Graduate*)
Reginald Elias Gourgey
John Colin Green (*from Graduate*)
Peggy Lilian Hodges
Karl H. Hoie (*from Student*)
George Hubert Hough
John Charles Michael Jones (*from Graduate*)
John Michael Storer Keen (*from Student*)
William Kelsey (*from Graduate*)
John Robert Poole Lansdown
Dennis Brigham Leason (*from Graduate*)
Frank Stanley Lester (*from Associate*)
Martin Madders (*from Associate*)
John Geoffrey Male (*from Graduate*)
Charles Milton Medcalf
Michael O'Donovan
Thomas Andrew Melville Pritchard
Derek Price Roberts
Lionel Vivian Frank Russell
Eric Sharrock
Leslie McDonald Sheppard
Giovanni Tagliaferri
Arthur John Taylor
Stanley Alfred Robert Taylor
Harold Joseph Tuffen
Albert William George Utting (*from Graduate*)
Arnold Hubert Voss (*from Associate*)
Joe Way Lee (*from Graduate*)
Roy Frank Whiteland (*from Graduate*)

Associates

Charles Edwin Allen
Geoffrey Robert Barratt
Ronald Edward Bellew (*from Student*)
Bertrand Brownlow (*from Student*)
David Seaton Colvin
Michael Wellinger Cross
Thomas Eugene Curran
Charles Wilfred Earnshaw
Herbert Fillingham (*ex Student*)
Dennis Howard Gilbert Griffin
Bernard Rupert Hayward
Eric Watson Hoole
Terence Charles McQuillin (*from Companion*)
Francis Kenneth Mason
Jack Clement Miller-Hall
Thomas Rutherford Morrison
Frederick James Mullins
John Dennis Oliver
Peter White
Richard Ivor George Whittington
John Robert Williams (*from Student*)
George Reginald Wrixon (*from Student*)

Graduates

John Anderson
Brian Peter Beal (*from Student*)
Donald Mathieson Devenish
James Stuart Hamilton
Roderick Cox Hastings (*from Student*)
John Moss Hearsey
Alan Micklem Hickling
Wilfred Michael Hobday
Thomas Murray Mansill
Raymond Douglas Leonard Meddick
Robert Rudd
Kenneth William Sambell
Henryk Soloniewicz
David John Wheeler (*from Student*)

Students

Harbans Singh Bhadwal
George Richard Bould
Harry Christensen
Edward John Dalley
Brian Thomas William Fogg
Edward Henry Green
Raymond Maurice Hankin
Graham Elliott Perry
Anthony David Poyner
Palamadai Muthuswamy Ramachandran
Kallur Nagabhushana Rao
John Skidmore
James Roderick Starkey
Clive Robert Turgoose

Companion

Peter Olford Deacon

News of Members

P. R. Allison (*Associate Fellow*), formerly a Performance Engineer with Bristol Siddeley Engines is now with the Air Registration Board as a Design Surveyor.

Air Commodore F. R. Banks (*Fellow*), has resigned from the Board of Bristol Siddeley Engines Ltd., and has left the company.

Neil W. Barford (*Associate Fellow*), formerly a Flight Test Engineer at Avro Aircraft, Malton, has joined Lockheed Aircraft Corporation, Georgia, as a Design Engineer.

Geoffrey A. Bunce (*Student*), formerly a Draughtsman, Vickers-Armstrongs (Aircraft) Ltd., is now Design Engineer B-70 Structural Components, North American Aviation Inc.

Sqdn. Ldr. T. Campbell-Burns (*Associate Fellow*), formerly in the R.A.A.F., is now a Development Engineer with Short Brothers and Harland Ltd., Belfast.

E. G. Davidson (*Companion*), is now Aviation Manager, Air B.P.

Handel Davies (*Fellow*), formerly Director-General of Scientific Research (Air), M.o.S., is now Deputy Director (Air), Royal Aircraft Establishment.

Donald Diamond (*Associate Fellow*), formerly with Airspeed Ltd., and Bristol Aircraft Ltd., is now Designer (Aircraft Furnishings), A. V. Roe and Co. Ltd., Manchester.

John E. Fox (*Associate*), formerly at Lockheed Aircraft Corporation, Georgia, is now with the Lockheed Missiles and Space Division at Sunnyvale, California, as a Design Engineer "A."

M. J. H. Giedroyc (*Associate Fellow*), formerly a Section Leader in the Design Office, Folland Aircraft Ltd., Hamble, now has an Administrative Sales Appointment with Hong Kong Aircraft Engineering Company, Hong Kong.

H. Greene (*Associate Fellow*), formerly an Aircraft Designer with A. V. Roe and Co., Canada, has joined the Grumman Aircraft Engineering Corporation, Long Island, New York.

Sqdn. Ldr. G. R. Hadfield (*Associate*), formerly at the Air Ministry (Weapons Engineering Division), is now

at H.Q., Fighter Command as Project Officer on the Lightning Aircraft.

P. A. HEARNE (*Associate Fellow*), formerly Sales Manager of British Oxygen Co., Aero Equipment, has been appointed Divisional Manager of the Guided Weapons Division, Elliott Brothers (London) Ltd., Boreham Wood.

J. M. HEARSEY (*Graduate*), formerly a Senior Stressman with Handley Page Ltd., has joined the Helicopter Division of Saunders-Roe Ltd., at Southampton Airport.

R. B. HEDGECOCK (*Graduate*) has left Folland Aircraft Ltd., and has been appointed to a Commission in the Technical Branch of the Royal Air Force at R.A.F., St. Mawgan.

J. C. HODGE (*Associate Fellow*), formerly in the Test Department, D. Napier and Son Ltd., Luton, has joined British Belting and Asbestos Ltd., Cleckheaton, in the Mintex Division, as a Sales Engineer (Development) in the Plastics Department.

G. C. LEGG (*Associate Fellow*), formerly Test Engineer with Avro Aircraft Ltd., Malton, is now Project Engineer with S. F. Bowser, Hamilton, Ontario.

JOHN M. MCDERMOTT (*Associate Fellow*), formerly with Avro Canada, Toronto, is now with North American Aviation Inc. of Columbia, Ohio, as a Structures Engineer.

M. B. MORGAN (*Fellow*), formerly Deputy Director (Air), R.A.E., is now Scientific Adviser to the Air Ministry.

L. F. NICHOLSON (*Fellow*), formerly Head of the Aerodynamics Dept., R.A.E., is now Director-General of Scientific Research (Air), Ministry of Supply.

R. W. PENNEY (*Graduate*), formerly a Graduate Apprentice at Hursley Park, is now at Vickers-Armstrongs (Aircraft) Ltd., Weybridge, as an Aerodynamicist.

R. V. PERCIVAL (*Student*), formerly a navigator with Gloster Aircraft Co., is now a Radar Navigator with de Havilland Propellers Ltd.

E. A. PERRY (*Associate*), formerly with Hunting Aircraft Ltd., Luton is now with the Pearl Assurance Company in Port Elizabeth, South Africa.

COLIN PIMLEY (*Associate*), formerly with National Presto Industries is now a Structures Engineer "A," Rheem Manufacturing Company, California.

H. H. RICKETTS (*Associate Fellow*), formerly Research Engineer with the Dominion Bridge Co. Ltd., Calgary, is now in practice as a Consulting Engineer at Calgary.

F. H. ROBERTSON (*Associate Fellow*), formerly Chief Project Engineer, Short Brothers and Harland Ltd., has been appointed Chief Designer, Light Aircraft.

E. J. SCANES (*Graduate*) has left the Royal Air Force and is now with the General Electric Company in the Osram Lamp Division.

S. SCOTT HALL (*Fellow*), formerly Scientific Adviser to the Air Ministry has been appointed Head of United Kingdom Ministry of Supply Staff (Australia) and Scientific Adviser to the High Commissioner.

M. A. SIDDIQUI (*Associate*), formerly working on inspection, Sperry Gyroscope Co. Ltd., is now a Technical Assistant, Aeronautical Research and Development Department, with the same company.

L. SMITH (*Associate Fellow*), formerly Lecturer at the Technical College, Bulawayo, S. Rhodesia, is now a Maintenance and Construction Instructor, Iranian Oil Refining Company, Abadan.

Captain G. R. SOFFE (*Associate Fellow*), formerly an Aeronautical Engineer, Maintenance Unit Air Corps, Baldonnel, is now a Development Engineer with Aer Lingus, and has been posted as Resident Representative with the Boeing Airplane Company, Seattle.

A. J. SPURGIN (*Graduate*), formerly with Vickers-Armstrongs (Aircraft) Ltd., is now a Control Engineer, Atomic Energy Division, General Electric Company, Erith.

V. TAYLOR (*Graduate*), formerly a Stress Engineer with Avro Aircraft, Ontario, is now a Stress and Vibration Engineer, Preliminary Design Department, Airesearch Manufacturing Corp., Los Angeles.

C. E. THARRATT (*Associate Fellow*), formerly Senior Technician is now Chief Rocket Development Engineer in Charge of Saunders-Roe Rocket Test Site at Highdown, Isle of Wight and is also in charge of the Company's Australian Operations.

DENNIS ULYETT (*Graduate*), formerly with Avro Canada, Toronto, is now a Structures Engineer, North American Aviation Inc., Columbia, Ohio.

R. P. WADE (*Associate Fellow*), formerly with the Stress Office, A. V. Roe (Canada) Ltd., is now with Convair Aircraft Corporation, San Diego as a Senior Structures Engineer.

Sqdn. Ldr. D. A. WALKER-ARNOTT (*Associate Fellow*), formerly at the Royal Air Force Technical College, Henlow, is now in the Directorate of Weapon Engineering at the Air Ministry, Whitehall.

M. A. WALLIS (*Graduate*), formerly with Avro Canada, Toronto, is now in the Aircraft Laboratory at Vickers-Armstrongs (Aircraft) Ltd., Weybridge.

ERNEST B. WESTON (*Associate Fellow*), formerly with the Ministry of Supply in the Engineering Division at Boscombe Down, is now Technical Assistant with the S.B.A.C. on airworthiness activities.

Sqdn. Ldr. G. WOOD (*Associate Fellow*), formerly A.R.D.E. (Sect. B.5), Fort Halstead, is now at the Air Ministry (D.D. OPS.(B.M.)), Whitehall.

LECTURES ON TECHNIQUES OF NON-DESTRUCTIVE TESTING AT BRUNEL COLLEGE

A course of ten lectures to be given on Wednesday evenings on the Techniques of Non-Destructive Testing will be held in the Physics Department, Brunel College of Technology, Acton, London W.3, from 7 p.m.-8.30 p.m. The first lecture will be given on 7th October 1959.

The fee for the course will be £1, and further details may be obtained from the Physics Department of the College.

THE FIRST ENGINEERING MATERIALS AND DESIGN EXHIBITION AND CONFERENCE

Engineering materials and design, embracing virtually every industry in the world, is the subject of a unique exhibition to be held in London next year—an Engineering Materials and Design Exhibition and Conference.

The first of its kind in this country, will be held at Earls Court from 22nd to 26th February 1960. It will be devoted solely to materials and components in engineering design. Associated with the Engineering Materials and Design Exhibition will be a Conference for engineering designers at which lectures and papers will be presented on ferrous metals and alloys, light metals and alloys, insulating and other electrical engineering materials, refractories, plastics, adhesives, powder metallurgy, rubber, inorganic materials, bearings, clutches, casting techniques, seals, drives, couplings, control techniques, and appearance design.

The Journal of the Royal Aeronautical Society

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

VOLUME 63 JULY 1959 NUMBER 583

THE FORTY-SEVENTH WILBUR WRIGHT MEMORIAL LECTURE

THE Forty-seventh Wilbur Wright Memorial Lecture, "Managing Aviation Technologies" by Mr. C. J. McCarthy, Hon. F.I.A.S., was given on 14th May 1959 at the Institution of Mechanical Engineers, Birdcage Walk, S.W.1 at 6 p.m. Mr. P. G. Masefield, M.A., F.R.Ae.S., Hon.F.I.A.S., M.Inst.T., President of the Society, presided.

MR. MASEFIELD: This Lecture, in which we honour the memory of Wilbur Wright and his brother Orville, is the highlight of our aeronautical year. We are privileged to have with us Mr. Charles J. McCarthy, a Past-President of the Institute of the Aeronautical Sciences, Chairman of the Board of Governors of the United States Aircraft Industry Association and Chairman of the Board of Directors of Chance Vought Aircraft. For many years, a tradition has been established that the annual awards of the Society should be awarded before this Lecture. Indeed, it is the first duty of each President on taking office, and it is my privilege this evening to present three Honorary Fellowships, two Honorary Companionships and eight medals. Election to Honorary Fellowship of the Society is the highest honour we can confer for eminence in the field of aeronautics, just as the Gold Medal of the Society is the highest honour we can confer for work of an outstanding nature in aeronautics.

Almost exactly fifty years ago, on 3rd May 1909, my predecessor twenty-two times removed, the third President of the Society Mr. E. P. Frost, had the honour of conferring both Honorary Membership—as it was in those days—and the Gold Medal of the Society, on the two Wright brothers themselves. Thus both I, stepping into this Presidential Chair, and those who are to receive honours this evening can feel that we go back along a line of tradition to the earliest days of manned flight and that this ceremony combines together, this evening, Anglo-American unity which has been so much a background to our aeronautical affairs in this Society and in the Institute of the Aeronautical Sciences throughout the years.

I have much pleasure in presenting the following awards:

Honorary Fellowship to: PROFESSOR J. ACKERET, Professor of Aerodynamics at the Eidgenossischen Technischen Hochschule, Zurich.

SIR WILLIAM S. FARREN, C.B., M.B.E., M.A., D.Sc., F.R.S., Hon.F.I.A.S., *Fellow*, Technical Director of A. V. Roe and Co. Ltd.

MR. S. B. GATES, O.B.E., M.A., F.R.S., *Fellow*, Chief Scientific Officer and Consultant to the Director of the R.A.E.

Honorary Companionship—to: MR. E. C. BOWYER, C.B.E., Director and Chief Executive of the Society of British Aircraft Constructors Ltd.

SIR WILLIAM HILDRED, C.B., O.B.E., M.A., Director-General of the International Air Transport Association.

The Society's Silver Medal—awarded for work of an outstanding nature in Aeronautics—to: DR. E. A. WATSON, O.B.E., D.Sc., Hon.M.I.Mech.E., Director, Joseph Lucas (Gas Turbine Equipment) Ltd. "for his achievements in the development of turbine engine combustion and fuel systems".

The Society's Bronze Medal—awarded for work leading to an advance in Aeronautics—to: D. G. KING-HELE, B.A., Royal Aircraft Establishment, Farnborough "for his contributions to earth satellite orbital theory".

The British Gold Medal for Aeronautics—awarded for outstanding practical achievement leading to advancement in Aeronautics—to: R. S. STAFFORD, C.B.E., *Fellow*, Technical Director, Handley Page Ltd. "for his outstanding practical contributions to aircraft design".

The British Silver Medal for Aeronautics—awarded for practical achievement leading to advancement in Aeronautics—to: D. J. FARRAR, M.A., *Fellow*, Chief Designer, Guided Weapons, Bristol Aircraft Ltd. and N. H. SEARBY, Ph.D., M.I.E.E., Manager, Guided Weapon Research and Development, Ferranti Ltd. "for their practical contributions to the development of guided weapons".

The Wakefield Gold Medal—awarded for contributions towards safety in Aviation—to: K. A. WOOD, Superintendent in Charge at the Atomic Weapons Research Establishment, Orfordness, "for his practical achievement in the development and application of electronic aids to all-weather approach and landing".

The R. P. Alston Medal—awarded for practical achievement associated with the Flight Testing of Aircraft—to: A. W. BEDFORD, A.F.C., *Associate*, Chief Test Pilot, Hawker Aircraft Ltd. "for his contributions to the technique of flight testing high-speed aircraft".

The N. E. Rowe Medal—awarded for the best lecture given before any Branch of the Society by a junior member of a Branch—in the age group 21 to 26 years—to: J. DUNHAM, M.A., G.I.Mech.E., *Graduate*, Rolls-Royce Ltd. "for his paper 'Damage to Axial Compressors' given before the Derby Branch of the Society".

No award was made this year for the under 21 age group.

(NOTE—The Society's Gold Medal was awarded to Monsieur Marcel Dassault and presented at the Louis Blériot Lecture on 12th March 1959.—Ed.)

We now come to the Wilbur Wright Memorial Lecture. Mr. McCarthy is an old and valued friend both of this country and of the Society. In his time he has been an aeronautical draughtsman, associated with the first crossing of the Atlantic by the N.C.4 flying-boat of the U.S. Navy; an engineer who has been intimately concerned with the most important developments in Aviation during the 1920's and 1930's; and he has had great experience of, and has contributed in a managerial capacity to, all those problems we know so well during the past twenty-five years. Mr. McCarthy is one of the leaders of American Aviation and his lecture carries on an unbroken tradition, in spite of two World Wars, of Wilbur Wright Memorial Lectures every year since the lecture was founded in 1912 immediately after the death of Wilbur Wright.

Before asking Mr. McCarthy to give his lecture I will read the following telegram:

"The Officers and Council of the Institute of the Aeronautical Sciences send congratulations and best wishes to its distinguished past President on the occasion of the reading of the Wilbur Wright Memorial Lecture before the Royal Aeronautical Society.—Paul Johnston."

The Forty-Seventh Wilbur Wright Memorial Lecture

Managing Aviation Technologies

by

CHARLES J. McCARTHY, S.B., F.I.A.S.
(Chairman of the Board, Chance Vought Aircraft Inc.)

1. Introduction

It is a great distinction and a highly esteemed honour to be privileged to read the forty-seventh Wilbur Wright Memorial Lecture. It is also a distinct personal pleasure to be here. Over the past 15 years I have made periodic trips to England to visit the aircraft companies, to witness the spectacular Farnborough displays of the S.B.A.C. and to attend the Anglo-American Conferences of the Royal Aeronautical Society and the Institute of the Aeronautical Sciences. This has afforded opportunities to observe and admire the rapid progress you have made in aeronautics, the brilliant achievements of British engineers and scientists and, more importantly, the chance to make and deepen warm and valued friendships. The joint meetings of the Society and the Institute are proving to be fruitful ground for the exchange of ideas and for becoming better acquainted. May I express the sincere wish that I shall have the pleasure of welcoming many of you to the Seventh Anglo-American Conference which will be held in October 1959 in New York.

The contributions of Wilbur Wright and of his brother Orville continue to be an inspiration to all of us. As we are now involved in the beginnings of space flight, it is particularly appropriate today that we should remember the men who brought to practical realisation man's ability to travel in the third dimension, the space above us.

A review of previous lectures in this series indicates an extensive range of subjects covered. This is a reflection of the impact that aviation has had during its very short life of less than sixty years. Probably no other aspect of technology has come so far in so short a time and made such substantial contributions to progress. Commercial flight is now completely accepted as a mode of travel. In fact, there are parts of the world where air transportation is commonplace and other modes are still almost unknown. Turbo-prop and turbo-jet air liners are on scheduled service. Straight and level supersonic speeds are an everyday occurrence with military aircraft. Missiles are now prime military weapons. A number of satellites are in orbit and projects are under way to put man into outer space.

The rapid advance of our technical progress has created a number of management problems which must be recognised and solved if the members of our industry are to discharge their obligations to nation, community, employees and shareholders.

The objective of my lecture is to deal with some of these problems. Although they are being examined from an American point of view, their counterparts in Britain will be recognised.

2. Technical Advances in Aviation

2.1. HISTORY AND GROWTH OF TECHNOLOGIES

2.1.1. *Early days of flight*

To appreciate fully the growth of the technology that has posed so many management problems, let me review briefly the history of flight. Aviation was started with an urgent demand for improvement that has been with us constantly from the days of Kitty Hawk; a demand that could be satisfied only by technological advancement and growth.

For a suitable starting point from which to develop this history it is appropriate to go back to 17th December 1903, when the Wright brothers made the first controlled flights, four in all, in a self-propelled heavier-than-air machine. During the last flight of the day, Wilbur Wright covered a distance of 852 feet in 59 seconds, attaining a speed of 37 miles per hour. By the end of 1907, only seven men in America had actually piloted powered aeroplanes. In January of 1908, a man of English birth, Henry Farman, succeeded in flying a circular course of one kilometre in his Voisin biplane and thus won the Deutsch-Archdeacon prize of 50,000 francs.

2.1.2. *Flight from 1914 to 1930*

Although the birth of aviation was in America, progress there lagged but development proceeded rapidly in Europe, with the result that most of the aeroplanes used in the First World War were of European design. At the beginning of the war maximum aeroplane speeds were generally below 100 miles per hour; by its end the standard scout fighter had a level flight speed of approximately 120 miles per hour. We were still in the bailing wire, spruce and fabric days of aviation but, nevertheless, we had accomplished a great deal. No longer did the aeroplane fly only a straight course with simple turns; manoeuvrability was a key word; the pilot's life had depended on this capability. The words Chandelle and Immelmann became accepted in the English dictionary. In the early days, one or two talented engineers, such as the Wright brothers, Martin and Curtiss, to name but a few in America, and Sopwith, de Havilland and A. V. Roe in England, supported by a structures engineer, an aerodynamicist or two and a few draughtsmen, comprised an adequate design team. They bought the engine from others and whittled out the propeller to fit. As H. M. Horner, Chairman of United Aircraft Corporation, has well expressed it "the major characteristic of this period was the passion for their work that marked that relatively small band of men who have given modern flight its present dimensions. They were so engrossed, indeed, that they

appeared completely indifferent to the scornful jeering they met on many sides."

From 1919 to 1930, progress was slow because government funds were meagre. For example, total U.S. government expenditures for aircraft for the fiscal year 1925 amounted to only 10 million dollars, yet aircraft technology continued to advance. Lindbergh's thrilling flight from New York to Paris in May 1927 was the most spectacular event of this period. It brought him enduring fame and gave a powerful world-wide impetus to aviation. The important technical advance was the emergence in England and in America of radial air-cooled engines of greatly improved power/weight ratio. The Wright Whirlwind which powered Lindbergh's aeroplane and the Pratt and Whitney Wasp, which in 1926 produced 410 horse power for a weight of 650 pounds, deserve mention. In the next ten years these lightweight power plants and the larger and more powerful radial engines which followed them, assisted by low drag N.A.C.A. cowling, had obsoleted the liquid-cooled engine and its radiators for substantially all commercial applications and the majority of military applications.

2.1.3. *The Second World War era*

In the late thirties, the rumblings of war were heard once again. The push was on to secure control of the air for both offence and defence. This period saw the birth of the Hurricane and Spitfire, the Corsair, Mustang and Thunderbolt. Except for de Havilland's Mosquito and Hornet, military aeroplane structures were so called "all metal," using lightweight, high strength alloys of aluminium and magnesium. Casting and forging techniques were improved by the metallurgists and were used extensively. The biplane disappeared and the aerodynamically cleaner monoplane took its place. For improved performance, the landing gear was retracted and high lift devices were added to hold down the landing speed. To operate these devices, improved high pressure hydraulic systems were used. The number of guns was increased, the calibre enlarged and the rate of fire stepped up. Electronic equipment operating in the very high frequency range was adopted for communications and navigation.

Power plant development paralleled airframe progress. I recall a discussion I had with Lord Hives in the summer of 1944. He stated that from 1939 to 1944 Rolls-Royce had boosted the power of the Merlin engine from 1,000 to 2,100 horse power and still had not yet reached the limit. On our side of the Atlantic, Pratt and Whitney's Double Wasp went from an initial 1,800 horse power rating to the point where, in the final stages of combat, advanced models with water injection delivered 3,400 horse power.

Increased horse power at sea level was only part of this development. The improved performance was carried to higher altitudes by the use of mechanically-driven and turbo-powered superchargers. To obtain maximum propulsive efficiency the constant speed, variable-pitch propeller was mated to the engine.

Improved performance, including combat altitudes greater than 30,000 ft. and level speeds in excess of 400 miles per hour, brought new problems. Oxygen had to be provided for the air crews and pressurised cabins were introduced. This brought aero-medicine into aviation and problems concerned with hypoxia, vertigo, and pilot fatigue had to be dealt with.

As an adjunct to military aviation radar became an important weapon for both offence and defence. In particular, it aided greatly in the defeat of the submarine. England led in this field and gave material help to America. It has been said that Sir Henry Tizard brought over the most precious package ever to cross the Atlantic—the resonant cavity tube for radar.

Two of the most significant steps in the technological advance of aviation appeared at this time—the gas turbine and the missile. For the first, aviation as a whole owes a tremendous debt of gratitude to Sir Frank Whittle. His brilliant pioneering work opened the door to the development of the powerful turbo-jet and turbo-prop engines of today. Before the end of the Second World War, the Germans introduced the missile as a bombardment weapon, first the pulse-jet V-1, then the ballistic V-2. These, I know, you well remember.

During the war engineering organisations expanded tremendously, the personnel in some of them numbered in the thousands. Many different kinds of engineering specialists were required to cope with the increased complexity of the aeroplane. However, when the war came to an end, government orders for aircraft were drastically reduced, with attendant drastic cut-backs in employment. This was, as we well know, a very unstable period for the Industry but, even though engineering efforts shrank, technological innovation continued.

2.1.4. *The modern era*

In the early 1950s, jet-powered military aeroplanes were operating in excess of the speed of sound and the term Mach number became a current measure of aeroplane speed. By the mid-1950s aeroplanes such as the U.S. Air Force Century series and the U.S. Navy Crusaders were operating at Mach numbers between 1·2 and 1·5. Currently aeroplanes such as the Air Force F-104 and Navy F4H-1 are flying at a Mach number of 2 and more.

What are the advances in the state of the art which have enabled the Industry to produce a truly supersonic machine? The availability of jet engines of high thrust was the prime requisite. Another was the improvement of existing strong metal alloys for the aeroplane structure and the introduction of others, such as titanium. Application of research results in aeroelasticity, dynamic analysis and aerothermodynamics was made possible by large scale computers. Servomechanisms have provided the pilot with irreversible power controls which, coupled with pitch, yaw and roll damping, ensure precise control of the aeroplane throughout its speed range. Electronic equipment has been integrated into the aeroplane, not only for communications and navigation, but also for flight control and armament fire control. In America, the personnel in the leading engineering organisations are again numbered in the thousands, and the skills are even more diverse.

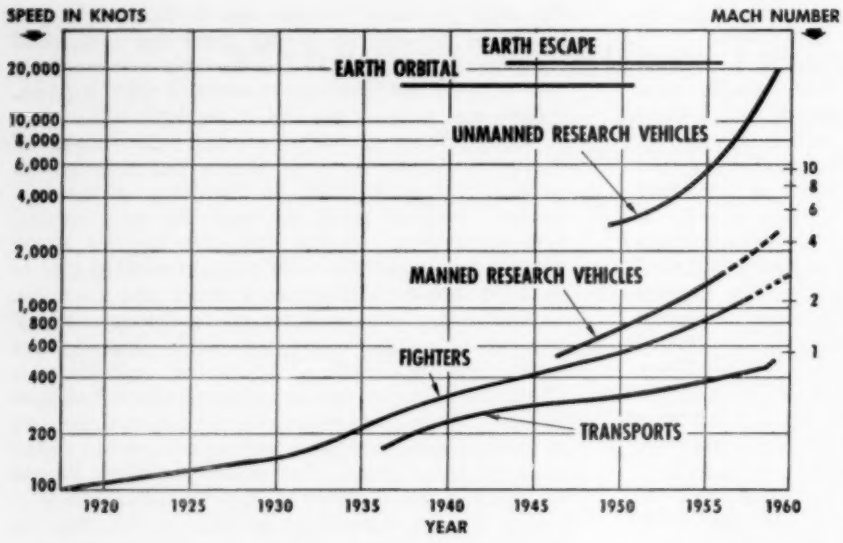


FIGURE 1. History of flight—speed against time.

The first half century of aviation has produced amazing advances in technology. In recent years some major technical breakthroughs have created new opportunities for development to excite the most creative and imaginative minds. An example is the North American X-15, planned to be the first manned spacecraft. This is essentially a research aeroplane, but may be the forerunner of the future. It is reported that it will reach altitudes of the order of 500,000 ft. and speeds up to 3,600 miles per hour. It is intended to prove many of the techniques needed for man to break away from the earth's atmosphere and explore outer space.

For many years maximum speed has been the accepted measure of progress and the capture of a new world record was a worthwhile prize. In some 55 years we have advanced from the 37 miles per hour speed of the Wright aeroplane to 1,404 miles per hour, the present official World Record. This fine performance is now overshadowed by the much greater speeds attained by research vehicles. The advance in speed for several types of aircraft and space vehicles is graphically shown on Fig. 1.

The gain in altitude performance for the military and research vehicles is impressive and has gone hand in hand with the improvement in speed. This is shown in Fig. 2. For the fighters the range of speed and altitude combinations which have been achieved in each of the past five decades is shown. Research vehicle performance is shown as a representative altitude and speed combination achieved in recent years.

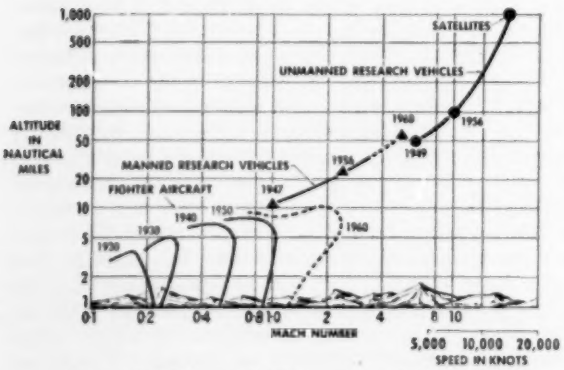


FIGURE 2. History of flight—speed and altitude.

It may be noted that, when we leave the atmosphere, Mach number loses significance, and we must return to a true speed measurement such as miles per hour. One might speculate that for space flight we may one day use a speed measurement referenced to the speed of light analogous to the Mach number referenced to the speed of sound.

2.1.5. *Missile and space era*

The missile era is so fresh in our minds that only brief comment is appropriate. The Intercontinental Ballistic Missile, of which the Convair Atlas is a typical example, employs liquid fuel rocket power plants and complex electronic gear for guidance and control. Such missiles, together with the satellites presently in orbit, mark the beginning of space flight. This new era is witnessing an integration of engineering skills with those of the scientists and mathematicians. We are building more powerful rocket engines, using both liquid and solid fuels, and expanding into new areas by developing exotic fuels and experimenting with the use of nuclear energy, electrical energy and solar radiation. Airframe structure and equipment are being designed to withstand the effects of radiation, meteorites and heating during re-entry into the atmosphere. Electronic equipment is necessary to provide guidance and navigation for lunar and interplanetary exploration. Aviation medicine has become space medicine; the medical profession is now concerned with providing an environment in space suitable for our future space men. This has brought to attention such problems as weightlessness and closed life cycles.

The achievements of the International Geophysical Year just ended, the placing of satellites in orbit, and the desire to get man into space have given a powerful stimulus to the expansion of research in many branches of science. The exploration of outer space is a subject of intense popular interest and a job of gigantic dimensions, as indicated by Fig. 3, for which I am indebted to Dr. C. S. Draper, head of M.I.T.'s

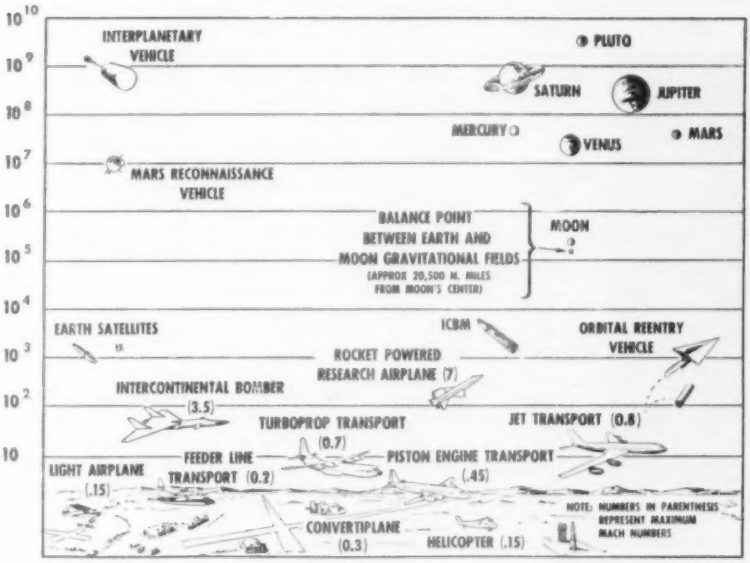


FIGURE 3. Flight vehicles—aeronautic and astronautic.

Department of Aeronautics and Astronautics. This chart emphasises the vastness of our solar system but also suggests that we should not neglect the many types of aeroplanes and helicopters, both military and civil, which are needed to perform useful and essential functions closer to the earth.

2.2. CHANGING CONDITIONS WITHIN THE INDUSTRY

2.2.1. *Trend in procurement*

The common characteristic in all this review of progress in aviation has been the rapidity with which entirely new developments have come into being. At the present time, these technological changes are truly radical and a large segment of the Industry is being forced to adjust itself to the new conditions. The time in which a particular weapon system is predominant is shortening and we have replacement systems already under development even before the earlier weapon has become fully operational. Illustrative of these changing conditions is the trend in government expenditures.

Figure 4 shows the manner in which defense dollars are being spent for aircraft, missiles and space vehicles in the United States today and a personal forecast of future trends. These expenditures are the amounts paid to industry for work performed or products delivered in a given fiscal year* and are not the total of new orders placed in that year. They are a fair measure of the rate at which work is being performed. Expenditures for military aircraft are declining, dropping from $8.5 billion† in 1958 to a planned $6.6 billion in 1960. It is my opinion that aircraft expenditures will approximate a rate of $6.0 billion for the next four or five years. On the other hand, expenditures for guided missiles have increased rapidly, jumping from 0.5 billion dollars in fiscal year 1954 to a proposed nearly 4.0 billion dollars in 1960. The rate of expenditures for missiles will likely rise somewhat more gradually in the future to a level approximating $5.0 billion in 1964. I have ventured to forecast expenditures for space vehicles, which Dr. Hugh Dryden recently predicted will soar into the billions after another couple of years.

In addition to government business the Aircraft Industry produces a substantial volume of civil aircraft, including commercial transports, executive and general utility aircraft. Sales in the calendar year 1958 are estimated at $2.0 billion and 1959 promises to be somewhat better.

2.2.2. *Trend in engineering*

The increased complexity of aircraft, missiles and space vehicles and the projection of their performance and operating environment from previous regions of experience require new technical skills, facilities and design tools. In the early days of aviation, a limited formal education and simple equipment sufficed for the pioneers to design and build flyable aircraft. As time went on, old skills required up-grading, more elaborate facilities and equipment were needed, and more formal education required for the designer. Fig. 5 is an attempt to show, at arbitrarily chosen intervals, some of the most important of the new skills which were introduced into the industry about that time, and those needed in the immediate future. Truly the future will require all

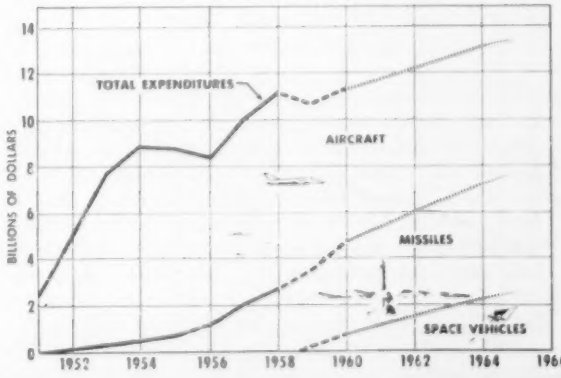


FIGURE 4. Military aircraft, missiles and space expenditures.

*U.S. fiscal year begins on 1st July of the preceding year.

†NOTE: One U.S. billion equals a thousand million.

CIRCA	1910	1935	1955	1965
TYPE OF VEHICLES	SMALL FLYING AIRCRAFT	SUBSONIC AIRCRAFT	SUPERSONIC AIRCRAFT AND MISSILES	MANNED SATELLITES, SPACE-SHIPS
NEW TECHNICAL AREAS	MECHANICAL ARTS	AERODYNAMICS STRUCTURE MATERIALS	THERMODYNAMICS ELECTRONICS NUCLEAR PHYSICS COMPUTING MACHINES AERO MEDICINE	RARIFIED GAS DYNAMICS SOLAR ENERGY MAGNETOHYDRODYNAMICS ASTROPHYSICS RADIATION PHYSICS PARTICLE PHYSICS SPACE NAVIGATION
HIGHEST LEVEL OF EDUCATION REQUIRED	HIGH SCHOOL OR SOME COLLEGE	B. S. SCIENCE OR ENGINEERING	PH. D. IN SCIENCE, ENGINEERING, MATHEMATICS	PH. D. AND POST PH. D. FELLOWSHIP
ORGANIZATIONS AND FACILITIES	GARAGE OR SHOP	ENGINEERING DEPT. AND FACTORY	ENGINEERING DEPT. ENGINEERING LABORATORY TOOLING DEPT. FACTORY	ENGINEERING DEPARTMENT RESEARCH AND MATHEMATICS GROUPS RESEARCH LABORATORIES FACTORY AND TOOLING

the talents we can muster to narrow the time lag between research and design. The close of this century may see the advent of interplanetary travel. The sciences required will undoubtedly include many more than those listed, many not well defined at the present time.

These increased requirements for technical skills and scientific data have inevitably increased the demand for engineers and scientists. Fig. 6 shows what has happened in the past six or seven years in the American Aircraft Industry. The ratio of the work force in engineering to the total has nearly doubled with a predicted steady increase in the future.

2.2.3. *Trend in management*

These revolutionary changes have presented new problems to management. Ralph J. Cordiner, Chairman of the Board and Chief Executive of the General Electric Company, concisely summarised the situation in the January 1959 issue of his company's "Defense Quarterly." "Where the need was once for production of existing designs, the prime need now is for designs that afford large increments of technical and military advantage over the weapons and systems they replace.

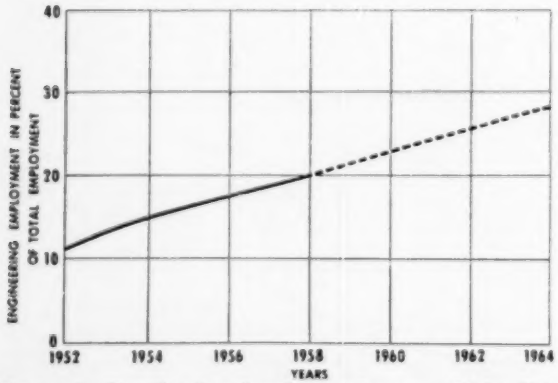


FIGURE 6. Growth of engineering employment. (Major U.S. airframe companies.)

by the Aircraft Industry.
by aircraft industry.

". . Where the need was once for facilities that could readily be converted to military production, the need is now for special facilities which are essentially non-convertible. . . . Where the need was once for a large number of general purpose components and subsystems, the demand is increasingly for complete systems and even super-systems. The need for components of very high reliability and advanced design remains, but they must more and more be planned in context with the concept and design of the system of which they are to be a part."

It is apparent that advancing technologies have forced our industry into new and difficult areas, requiring highly educated specialists, intensive research in many sciences and a more flexible organisation.

3. Managing the Technologies

3.1. THE TECHNICAL MAN

3.1.1. *He is an individual*

As we proceed into the Space Age we must rely more than ever before on our technical people, the engineers and scientists who make up an ever-increasing proportion of the various aircraft industry organisations.

Who and what are these people—the engineers, the scientists on our technical staffs?

The technical man is many things. Basically, he is a person of high intelligence, possessing a well-developed curiosity. Usually, he is self-motivated, has a strong sense of responsibility and a need for freedom of action. More than anything else, however, he is an individual and therefore motivated by the same four factors common to all of us: the desire to belong, the desire for recognition and attention, the desire for variety and change and the desire for security.

The desire for recognition is perhaps the most powerful incentive to be satisfied. This includes recognition by subordinates, associates, supervisors, and management. And—very importantly—recognition in his own field of endeavour. A physicist, for example, may be more concerned with his stature among physicists than his stature in his firm.

Many of our engineers and scientists are, of course, truly dedicated men. Financial rewards need only be fair and just.

In general, engineers tend to accept responsibility for the work of their groups and so enter the field of management. However, some engineers and scientists

have no inclination nor aptitude to become supervisors but do wish to rise in their technical specialities. It seems reasonable that they should be able to climb the ladder of salary and prestige without having to assume the administrative duties which are associated with a supervisor's job. Parallel ladders of progress, with the same salary potential and attendant privileges for both the administrator and the technical specialist, are a prerequisite for good morale.

The technical man also expects that his firm will provide him with opportunity for advanced study and professional development. He desires increased use of technicians and engineering assistants, to lessen his administrative load and his volume of paperwork. He needs the most modern tools—electronic computers, wind tunnels, model shops, laboratories.

Our industry has the immediate problem of better utilisation of available technical manpower and the long-range responsibility of helping to increase our national resources of trained people. Frenzied recruiting practices and reckless bidding up of starting salaries are not the answer. Earnest consideration should be given to the more extensive use of various types of incentives. In sound human relations there is a promising basis for inspiring our technical men to greater creativity and production.

3.1.2. *The engineer-scientist in management*

In the early days of aviation, the days of pioneering efforts in invention and design of a useful product, the managers were those who had created the enterprise and could personally contribute effectively in development of the product.

Then, as aviation grew up into big business, the management function was taken over more and more by non-engineering personnel. Production and finance assumed roles of greater importance.

Today, science and technology exert paramount influence and are a major factor in many management decisions. Never before has the product of engineering and scientific minds and skills been so essential to the security of the Free World and to its future. Science has an increasingly more powerful impact on our lives, our economy, our national and international relations. There is, therefore, increasing dependence on the informed judgment of our technical people who should, and do, participate to an important degree in the decision-making functions of management.

3.2. EDUCATION

There is vigorous competition for the services of top-notch, creative men with broad backgrounds and with certain specialities. Experienced men are at a premium for research and development in such fields as missile controls and fuels, satellites and "outer space." For the first time, industry is finecombing the country for mathematicians, astronomers, astrophysicists, meteorologists, geophysicists.

Figure 7 is an estimate of the engineering graduate situation based on studies by the National Science Foundation and the United States Department of Health,

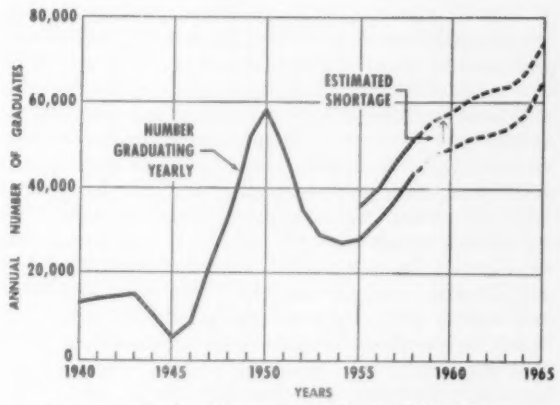


FIGURE 7. Engineering graduates in the United States.

Education and Welfare. The studies indicate an average shortage of 10,000 new engineers through 1965.

It is possible that the shortage may exceed this estimate because a recent report suggests that the predicted level of graduates may not be realised. In January 1959, Secretary Arthur S. Flemming released a preliminary report from the Office of Education on 1958 autumn enrollments in engineering. A seven-year trend in freshman engineering enrollments was reversed and the 1958 total dropped 11 per cent below 1957. The decline was disappointing in the light of a 6·2 per cent increase in the total first year enrollment in institutions of higher education. Let us hope that this decline is a temporary one. The report did contain the encouraging information that graduate students working for a master's degree in engineering rose from 24,136 in the autumn of 1957 to 28,154 last autumn, while those preparing for doctorates in this field rose from 4,180 to 4,778. It is in these categories that the most acute shortages are felt.

Russian advances in the military arts threaten our security on all fronts from I.C.B.M.s to submarines, but the Soviet Union's spectacular successes in the launching of satellites have highlighted a threat which may be even greater than the threat of military weapons. That danger lies in the schoolrooms of the Soviet Union. For a number of years, Russia has been turning out engineers, scientists and teachers in far greater numbers than the United States. Currently, the United States is graduating slightly over 40,000 engineers annually to Russia's 80,000.

Some, of course, will take issue, but Dr. Edward Teller contends that the United States already has lost the technological race to Russia for at least a decade. "Within 10 years," Dr. Teller has said, "the Soviets will have the best scientists in the world. I am not saying this will happen unless we do this or that. I am simply saying that it is going to happen. The time has come to talk about the U.S. recovering the world lead in science, not to keep that lead."

There may be neither reason nor need for the United States to turn out as many engineers as the Soviet Union but it is desperately vital that we more than match Russia in overall technological progress.

One of our weakest areas is the distressing shortage of qualified teachers. The demand for engineering graduates in recent years has forced the bidding so high that industry has been offering to the average Bachelor of Science graduate salaries which are on a par with, or above the level of, the salary paid to an instructor at his college. Something must be done—and done quickly—to make teaching a more attractive career. We cannot hope to increase the number and quality of our engineering graduates—the top-flight engineers and scientists of the future—without an enlarged, qualified and satisfied corps of teachers. This will require not only raising college and university teachers' salaries to be more in keeping with those paid by industry but also restoring the social prestige which used to be more generously accorded to the teaching profession. This statement applies with equal force to the grade school and high school teacher.

It is estimated that the United States currently faces a shortage of nearly 1,000 engineering teachers, with 9,500 new teachers required by 1966. A report issued by the Rockefeller Brothers Fund warns: "By 1969, high schools will be deluged with 50 to 70 per cent more students than they can now accommodate; by 1975 our colleges and universities will face at least a doubling and in some cases a tripling of present enrollments."

This challenge is being met in part by substantially increased contributions from private sources directly to the colleges and universities and in the form of scholarships and fellowships to deserving students. The Council for Financial Aid to Education reports that private gifts and grants to America's colleges and universities for educational and general purposes, for plant expansion and for endowment, have increased from $258 million in the year 1949-50 to $864,000,000 in 1957-58. During this period total school budgets rose from $2.4 billion to $4.1 billion. The Council report forecasts that the school budgets will more than double to $9.0 billion by 1969-70 and suggests that annual private contributions should increase to $1.4 billion by that time.

A recent informal survey of the aid-to-education programmes of a dozen of the larger aircraft firms shows that the industry is alert to its responsibilities and is doing its share. Its programmes, naturally, are primarily directed to advancing scientific and engineering education.

The federal government has launched an elaborate programme in the National Defense Education Act of 1958 which could involve the expenditure of as much as $880 million over a four-year period. The funds made available for the first year amount to only $40 million but it is expected that they will be increased as the programme develops.

These developments reflect a growing awareness that our future progress—and quite possibly our very survival as a member nation of the Free World—may depend on our technological competence.

The gross national product of the United States—the sum total of goods and services produced—has increased from approximately $90 billion in 1939 to well over $400 billion.

When it was necessary to defend with force of arms our right to exist as a free people, 40 per cent of our gross national product was spent for defence. Currently, we are spending 10 per cent of this gross national product to maintain our military strength.

How, then, knowing as we do that the threat we are failing to meet in our classrooms may be more dangerous than the threat of the mightiest weapons of war, can we justify spending only one per cent of our gross national product for education?

Robert D. Calkins, president of the Brookings Institution, has this to say: "In view of the importance of higher education to the future of this nation it is shocking that so little attention has been given to the economic aspects of this enterprise. . . .

"The question often arises whether the economy can stand larger support for education. The answer is clear. It can, but it will not until the people consider education to have a higher priority of importance than they ascribe to it today. . . . The expenditure for education could be considerably increased without disastrous results for the economy."

3.3. RESEARCH IN THE AIRCRAFT INDUSTRY

3.3.1. *Growth and importance of research*

Applied research, both theoretical and experimental, has always been the backbone of the Aircraft Industry. Few industries apply the current "state of the art" so closely in their product. The time from wind tunnel to flight operation is brief. Indeed, the cycle from invention through development and on to production is ever shortening. The life span of the turbo-jet engine for first line military weapons is destined to be shorter than that enjoyed by the reciprocating engine. Even for those complex weapon systems whose development time seems long, the incorporation of new ideas is accelerated by the pace of research.

Aircraft companies initially depended for their research data on the National Advisory Committee for Aeronautics and some of the universities. For the most part industry simply reduced this research to design practice, but now aeronautical research has broadened and become more complex. From the relatively straightforward structures-test laboratory and wind tunnel, research and development requirements extend over the whole spectrum of the physical sciences and its many specialities. In fact, research in ideas themselves, in the field of operations and systems analysis, is an important part of this new pattern. It is no longer possible to wait for research reports from laboratories outside the company. The competitive demand to apply promptly any developments in prototype and production aircraft requires that research specialists be vigilant. From company research programmes come not only new concepts, but also the perception to interpret and make use of the vast output of other research agencies. Our customers have stressed the importance of technical competence in winning contracts. In this fast moving business "technical competence" translates directly into "company research."

Company research, in addition to being vital for survival in a competitive industry, is increasingly

important to the customer. Due to the mounting cost of military aircraft he can seldom afford the luxury of alternate or "back up" models. The one weapon system chosen to fill an operational requirement must be successful. The best assurance the customer has that this will be done is the capability of the contractor which, in turn, stems largely from company-sponsored research. That many research programmes result in some duplication is the very stuff from which healthy competition is made. As individuals in a free enterprise system, we gladly pay the cost of industrial research in the price of the everyday products we purchase. We know this leads to better and more economical products and a better standard of living. We do not demand that Ford and General Motors co-ordinate their research programmes! The military services, and we as taxpayers, will find it cheaper in the long run to support a profit level that will permit well managed research programmes in the Aircraft Industry.

An accurate appraisal of the magnitude of research expenditures in the Aircraft Industry is difficult to obtain since published surveys generally include government-sponsored research and development (including prototype aeroplanes and missiles). So let me present the overall industrial research picture in America and draw a comparison. Fig. 8 shows the growth of all private industrial research and development in the United States over the past fifteen years and a prediction of the future. This curve was derived from reports and bulletins of the National Science Foundation and the U.S. Statistical Abstract of the Department of Commerce. The rise has been phenomenal; since the close of the Second World War industry investment in research has increased more than fivefold. The complexity of products in the Aircraft Industry has increased at a faster rate than it has for the overall industrial picture. Consequently, the portion of industrial research and development performed by the Aircraft Industry has probably increased at a rate greater than that indicated on the figure. Certainly it has been the experience of my company.

A word is needed here regarding the adequacy of so-called "basic" research. Dr. Mervin J. Kelly, Chairman of the Board of Bell Telephone Laboratories,

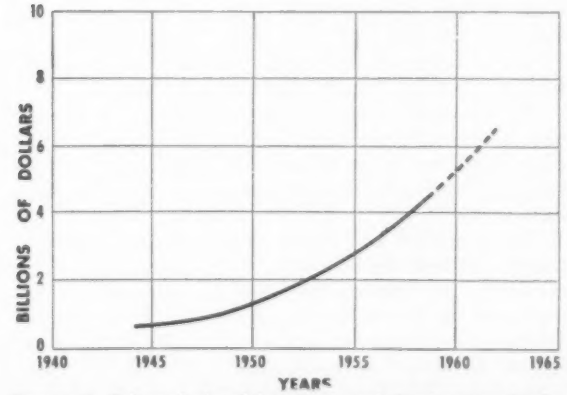


FIGURE 8. Private industrial research and development in the United States. (One U.S. billion = a thousand million.)

in an address accepting the James Forrestal award from the National Security Industrial Association, stressed the importance of basic research. He stated that of the total research and development effort of the United States only 5 per cent was spent on basic research and "it should be twice this percentage." Major General M. C. Demler, Director, Research and Development, H.Q., U.S. Air Force, had a similar comment to make in a recent talk when he said: "Regardless of the size of our military research and development budget, we are still funding only half of our requirements in applied and basic research."

The ballistic missile and manned space vehicles have created new problems that demand fundamental or basic research for adequate solutions. The urgency of these projects requires the individual companies to do a great deal of this. However, we should not overlook the importance of university research. This requires a twofold effort. First, we must provide financial assistance for undefined university research. Second, many defined problems can be, and are, assigned to universities. New inputs, fresh ideas and economy of funds generally result.

3.3.2. *Management research responsibilities*

This new position of research in aircraft firms has created new responsibilities for management. Research programmes must be outlined with sufficient latitude for creativity to flourish. Inventions cannot be scheduled, yet research must be productive. The researcher must be freed from detailed requirements and other administrative burdens. Yet, research efforts must be led towards overall company and national objectives. Continuity of effort in research both as to direction and magnitude is most important. Research, to be effective, cannot be turned on and off at will. A research man should be free to pursue new ideas in his speciality—not used too frequently as a technical fireman to come to the rescue of the production line.

The measurement of research results presents a special problem. Significant breakthroughs are easily recognised but are few in number. The intangible benefits of research many times go unnoticed while management seeks some measure of success for its investment in research. The ability to improve current production is often overlooked as a by-product of research. When a breakthrough does occur, the fact that an adequate portion of the engineering staff is familiar with the new development and ready to reduce it to practical application is usually the result of several years of previous activity in that field. Management must look for the greatest value from its research in long-term improvement, rather than in the results obtained on specific projects.

Because of the fast moving pace of research, we must extend our vision and employ the greatest wisdom in the selection of business endeavours. The many paths opened up to management by the scientists present, at times, an almost bewildering number of choices. The tendency is either to spread efforts too thin or jump from one type of venture to another. Either of these approaches can lead to failure. A

company must chart its course and then prepare itself for the technical weather that may be expected; and yet it must be sufficiently skilful that it can change its tack to take advantage of new situations as they arise. The co-ordination of company long-range objectives with proper guidance of research must occupy a good share of management's time. The selection of the proper areas of product development in the face of many possibilities requires the utmost in corporate judgment.

3.4. FINANCING THE TECHNOLOGIES

The aviation industry in the United States today has the primary responsibility for the development and production of the nation's military and civil aircraft, guided missiles, and space craft and other comparable vehicles. Its financial health and stability are consequently a matter of major concern.

We all recognise that for any business to be strong and progressive it must be able to earn a reasonable profit from which to pay its shareholders for the use of the money they have invested in the company and to provide funds for company-sponsored research and development and for the continual modernisation of its facilities and equipment. The rapidly advancing technologies in our industry and the fact that about 82 per cent of current sales are to the government make this a particularly challenging problem both to industry and government. Historically, a company's financial strength resulted from its "production" sales and not from its "research and development" sales. With production runs being sharply curtailed as a result of the increased capabilities of modern weapons, unit costs have risen sharply, and with the nation operating under a relatively fixed budgetary ceiling for procurement of weapons, it is apparent that fewer and fewer production projects can be afforded or supported. This, in turn, means less production work for individual manufacturers and reduces the individual firm's basic financial capability.

Instead of liberalising and simplifying procedures, government procurement regulations steadily grow more restrictive regarding the cost of many normal business expenses and research and development costs which are not directly applicable to specific government contracts. The industry's profit margin, after taxes, has steadily declined from 3·9 per cent of sales in 1955 to 2·6 per cent in 1958, compared with approximately 5·2 per cent for major U.S. manufacturers.

Even these modest earnings are not certain because they are subject to review by the Renegotiation Board, which has assessed severe penalties against a number of companies. To quote Orval Cook, President of the Aircraft Industries Association: "Furthermore, the delays inherent in the present renegotiation process, and the fact that only the Renegotiation Board itself can define what it considers to be 'excessive profits,' certainly contributes nothing to the financial strength of the industry."

Because of its need for increased working capital the Aircraft Industry has been conservative in its dividend policies and has retained for growth approximately 60 per cent of its net earnings, the highest reinvestment rate of any industry. That these retained earnings have been insufficient is shown by the need to increase borrowings which, in the case of 15 major firms, have climbed from a total of $25 million in 1950 to $689 million at the end of 1958.

There is, of course, an additional source of financing —the equity market. However, because of the relatively low earning rate of the industry, its high reinvestment rate and its lack of stability, aircraft securities, generally speaking, do not compete successfully on the money markets.

There are several factors which contribute to increasing the demand for capital. To keep up with our dynamic technology and to remain in business, industry has been forced to reinvest in new plant, research, test and production facilities at an unprecedented rate. There are hundreds of thousands of square feet of factory space suitable for conventional aircraft assembly which are not being used, but new plants are indispensable to accommodate the new fabricating techniques and to achieve the tolerances, performance, and reliability required for our modern weapons. Because of budgetary limitations the government is relying increasingly on industry to provide these new and costly facilities.

Recent government actions have further increased the necessity for additional working capital. In mid-1957, due to fiscal stringencies of its own, the Defense Department cut sharply the scale of progress payments for work completed on cost-plus-fixed-fee contracts from 100 per cent to 80 per cent. Payments on incentive type contracts, which in 1954 had been dropped from about 90 per cent to 75 per cent, were lowered further to 70 per cent.

In the commercial field, the new jet and turbo-prop aircraft which are now coming off the assembly lines represent a new era in transportation and will provide greatly increased speed and comfort to the traveller. However, their construction has imposed severe financial strains on the manufacturers. The five companies building the turbine-powered fleet estimated that nearly $1.6 billion was spent in research, development, testing, facilities, production and associated costs before the first aeroplane was delivered. In addition, substantial sums for these purposes were spent by the engine manufacturers and the 5,000 suppliers, subcontractors and vendors to develop new types of equipment especially adapted to the new high performance aircraft.

Development costs have been heavy and it appears that in spite of large initial orders, amounting to some 600 aeroplanes, most of the companies need to book additional business to come out whole on their investment.

The intention and efforts of the American government to prevent the defence budget from rising beyond current levels exposes the military contractor to the hazard of rather violent fluctuations in his work load. With each new weapons system requiring fantastic sums for development, the government can no longer afford the expense of carrying along a parallel system. Budget officers are on the alert to spot and eliminate less

glamorous systems which, as Secretary of Defense McElroy expressed it, "have been overtaken by events." I speak with feeling because two important Vought development projects, an aeroplane and a missile, were abruptly terminated last December. A similar fate overtook our Canadian friends a few weeks later when the Canadian government cancelled the Avro Arrow interceptor and the Orenda Iroquois turbo-jet engine contracts.

Such experiences are no novelty to this audience, many of whom were affected by the changes in the British Aircraft Industry which resulted from the government decisions announced in the famed Defence White Paper of 1957. To be able to withstand these shocks, it behoves defence contractors to diversify their activities both within and outside the military. This had been appreciated even before 1957 and a substantial diversification has been successfully achieved by a number of companies both in England and in the United States.

If the Aircraft Industry is to continue to move back the frontiers of science in the development of military weapons systems, the military customers must be more realistic in negotiating the financial agreements with the producers. Industry must be reimbursed at a rate which allows an appropriate level of research and development and permits introduction of innovations and improvements in its products to assure the nation of a strong defence capability. The government must take into account advances in the state of the art and changing technologies in considering the allowability of costs for new test facilities and the like. Finally, contract prices should be adequate to permit an efficient manufacturer to earn a reasonable profit, considering the sales volume, the amount of capital investment and the risks taken. Without a recognition of these principles the industry cannot maintain its financial health.

I would like to quote an excerpt from a report, dated December 1958, of the Aviation Securities Committee of the Investment Bankers Association of America. The report details the "unique partnership between the government and the aviation industry," and reliance "upon a few private aircraft manufacturers to maintain the Free World's strategic air and rocket superiority over the combined resources of the most powerful Communist aggressor in history." It concludes: "Primarily, it is a problem of recreating the economic soundness of a crucial industry in order to re-establish its financial priority in our capital markets commensurate with its strategic priority to our nation."

3.5. MANAGEMENT METHODS

The supervision of the design and development of a modern weapon system presents a formidable task to management. A weapon system comprises not only the optimum combination of an aircraft or missile with its armament or warhead, airframe, propulsion, electronics and other sub-systems, but also methods for its effective utilisation, including ground support equipment, operational launching sites, training aides and other equipment needed to make it ready for action. Expenditures are likely to be measured in billions of dollars by the time the new weapon has reached a fully operational status.

To warrant such cost, the new system must offer decided superiority over earlier systems, which in turn requires the integration of components whose design is at the outer limits of our knowledge and whose development must be paced to fit the overall schedule for the complete system. Military services are often not adequately staffed to manage such a complex and highly technical operation and increasing reliance is placed on a single prime contractor to assume the responsibilities of weapon system manager on behalf of, and under the supervision of, the government service. This concept is basically sound and workable.

North American Aviation, for example, is manager of two advanced systems for the U.S. Air Force, the B-70 bomber and the F-108 fighter. J. L. Atwood, the company's President, had this to say in a recent address outlining plans for the management of these large programmes: "The weapon system development concept in turn means adapting and bringing together, in accordance with a plan, various lines of development to achieve such a self-sufficient instrument of combat. The objective is simply to achieve operational availability of the most advanced equipment at the earliest possible date and at minimum cost.

"It would appear from this that there is really nothing new about the weapon system concept other than the name. It has always been the objective of a nation to bring together all the skills available to it in preparing the common defense. And it has always been the objective of military planners, from the earliest times, to have stones to go with the slings, arrows to go with the bows, and bullets to fit the guns. These seem to me the key ideas of weapon system development—the meshing of many talents to achieve timely availability of weapons that are operationally complete and ready."

Modern weapons systems are so tremendously expensive that only a limited number can be supported and the U.S. government must be quite certain of its ground before going beyond the early phases of development. "Aviation Daily" recently reported that Secretary of Defense Neil McElroy had told a Congressional committee that a decision to begin production of a certain missile was being delayed not because $300 million to $700 million would be required immediately, but because an affirmative decision would involve about $7.5 billion before the programme was complete.

There is intense competition in our industry to participate in such new programmes as are initiated. And because even the largest firms do not possess all the specialities needed to execute a complete system, it is common for a joint proposal to be submitted by an informal group, offering the combined experience and resources of half-a-dozen or more companies.

This practice is likely to persist because the team can prepare a strong co-ordinated proposal, linking together the different systems and sub-systems required. Also, it is helpful to the smaller firm, which may be outstanding in some speciality, to have its talents recognised and be given an opportunity to join with others

in an effort in which, alone, it would be unable to compete.

It is apparent that extraordinary management flexibility and skill are required in this intimate relationship between the prime contractor and the associated firms. For the venture to succeed there must be mutual confidence, conscientious effort and a frank interchange of information on costs, progress and the technical difficulties which arise. The task is not made easier by the fact that our team mates on one project may be among our competitors on another.

My company has participated in a number of such team projects, sometimes as the prime contractor and sometimes as a sub-contractor. For example, we are a member of the Boeing team which is working on a study phase of the Dyna-Soar, a boost glide space vehicle for the Air Force, in competition with a Martin-Bell team. We observe with interest that the team concept is also being used in England and that the proposed tactical support and reconnaissance aircraft, TSR.2, will be undertaken jointly by Vickers-Armstrongs and English Electric, while the development of the power plant will be the responsibility of a new company, formed out of Bristol Aero-Engines and Armstrong Siddeley Motors.

Carrying the weapon system team concept one step farther, it is reasonable to anticipate that co-operation of firms on a weapon system will extend beyond national boundaries and be international in scope. We have seen the successful exchange of licenses both ways between England and America. We read that several countries are joining with Britain on atomic power developments and there has been an impressive and inspiring example of world-wide teamwork during the International Geophysical Year just ended.

4. Summary

In summary, a brief review of the history of flight reveals the amazing speed at which aviation has advanced from the pioneering days when management was a simple matter indeed. One man could be the chief executive in a literal sense; head the company, raise the capital, design the aircraft, help build it with the assistance of a few mechanics and elementary tools and, finally, flight test the finished product himself.

Today the job of management has become exceedingly difficult. The manager has to assemble and rely upon groups of highly educated scientists and engineers trained in a broad sweep of disciplines, make provisions to facilitate their continuing study to keep up with the growing fund of knowledge, provide research facilities and elaborately equipped plants to carry on essential research and to manufacture a complex product. It is a risky business with strenuous competition and a relatively low return. Individual projects have grown so big and so intricate that the military services find it advantageous to transfer management responsibilities to a private weapon system manager. And, finally, even the largest corporations cannot do the job alone and must join forces with other firms, both large and small and with thousands of suppliers and vendors.

It is management's job, also, to carry a large share of the burden of attempting to solve two significant and urgent problems: —

1. We must find more effective methods of accelerating research in all technical areas, both civil and military.
2. We must develop better means of speedily applying this new knowledge to the selection and prosecution of programmes required for safeguarding our way of life.

Do you not sometimes pause and wonder why anyone would wish to become involved or remain in such a precarious business? To me, the answer is found in the challenge of a swiftly changing, always advancing technology and in the satisfaction one derives from feeling he is making a contribution to strengthening the armour of the Free World.

MR. MASEFIELD: This has been a forthright lecture with some points on which we can ponder deeply on various aspects of the business in which we are all engaged. I will now ask Sir William Farren to propose the vote of thanks. This is particularly appropriate because Sir William and Mr. McCarthy are old friends—Sir William was President of the Society and host to the Institute of the Aeronautical Sciences at the Anglo-American Aeronautical Conference in 1953 when Mr. McCarthy was President of the Institute.

SIR WILLIAM FARREN: Mr. McCarthy and I are indeed old friends. I remember being in Hartford early in 1953, discussing the forthcoming Anglo-American Conference with him. We decided that the views of our two Societies have much in common, even if their names are different. We decided that joint conferences were therefore good things, and hoped they would continue. At present Anglo-American Conferences are continuing, and although I suppose that the future may bring some changes, I hope that at least, in years to come, whatever the interval may be, we in this country and our friends in the United States will meet and cement those friendships which Mr. McCarthy mentioned at the end of his lecture.

There is one respect I think in which the differences in the titles is worth some thought. The Royal Aeronautical Society, nearly a hundred years old, was founded long before people flew, in days when our members were simply interested in flying. The Institute, founded in the days when science had become a recognised activity for engineers, has never quibbled at calling itself the "Institute of the Aeronautical Sciences". I believe that is a good thing. In our own Society we now find our main interest in what Mr. McCarthy has spent most of his lecture discussing, the situation which aviation has now reached, when the science of aviation in all its aspects is in charge. This is the Space Age. Mr. McCarthy called it the Age of the Technical Man, as he might have said that the Victorian and Edwardian ages were the Age of the Engineer. Mr. McCarthy has joined engineering and science together as, I think, most of us would now wish to do. But while we are told from all sides that the supply of men is short, paradoxically there are many places where there is no great need for them—to their dismay.

In some of the graphs Mr. McCarthy has engaged in the unscientific procedure known as "extrapolation"; a temptation to which most people talking about the future of aviation are apt to fall victims. "Extrapolation" can be substantially misleading. One of those things called "step functions" can come in and it is well known that there is no means of predicting whether, when, or where they are coming. Mr. McCarthy is obviously far from pessimistic. But it can not be expected that the United Kingdom will spend anything like the

amount Mr. McCarthy seems to believe that the United States will spend in the next few years on aircraft, missiles and space travel combined. Even so, I think we can join with Mr. McCarthy in what I would describe as the "reasoned optimism", which is the keynote of the lecture. The wind is turning.

The difficulty of management of the affairs in which we are all engaged—technicians, technologists, engineers, engineer-scientists, whatever names you like to use—is great. Indeed, I believe that, both here and in the United States, we are still learning how to do it. New names do not solve old difficulties.

We are grateful to Mr. McCarthy for coming from Dallas, Texas, to give his lecture. This I know you have all enjoyed, and I ask you to show your appreciation by your applause.

Following the Lecture a dinner was given by the President and Council at 4 Hamilton Place at which the following were present:—

Professor J. Ackeret, Hon.F.I.A.S., Director of the Aerodynamics Institute, E.T.H. Zurich; Honorary Fellow 1959.

Dr. A. M. Ballantyne, T.D., B.Sc., Ph.D., Hon.F.C.A.I., F.I.A.S., F.R.Ae.S., Secretary, Royal Aeronautical Society. Air Commodore F. R. Banks, C.B., O.B.E., M.I.Mech.E., Hon.F.I.A.S., F.R.Ae.S., Director, Bristol Siddeley Engines Ltd.; Vice-President, Royal Aeronautical Society. Mr. A. D. Baxter, M.Eng., M.I.Mech.E., F.R.Ae.S., Chief Executive, Rockets and Nuclear Energy, de Havilland Engine Co. Ltd.; Member of Council. Mr. A. W. Bedford, A.F.C., A.R.Ae.S., Chief Test Pilot, Hawker Aircraft Ltd.; Alston Memorial Medallist 1959. Mr. E. C. Bowyer, C.B.E., Director and Chief Executive, Society of British Aircraft Constructors; Honorary Companion 1959. Sir Aubrey Burke, O.B.E., Deputy Chairman of de Havilland Holdings Ltd.; President, Society of British Aircraft Constructors.

Sir Sydney Camm, C.B.E., F.R.Ae.S., Director, Hawker Siddeley Aviation; Director and Chief Engineer, Hawker Aircraft Ltd.; Past President, Royal Aeronautical Society; Member of Council. Mr. T. Carter, Civil Air Attaché, American Embassy. Dr. W. Cawood, C.B., C.B.E., B.Sc., F.R.Ae.S., Controller of Aircraft Research and Development, Ministry of Supply; Member of Council. Dr. J. S. Clarke, O.B.E., Ph.D., M.I.Mech.E., F.R.Ae.S., Director, Joseph Lucas Ltd. Professor A. R. Collar, M.A., D.Sc., F.I.A.S., F.R.Ae.S., Professor of Aeronautical Engineering, University of Bristol; Member of Council. Mr. J. R. Cownie, B.Sc.(Eng.), Grad.R.Ae.S., Chairman, Graduates' and Students' Section, Royal Aeronautical Society; Member of Council. Sir George Cribbett, K.B.E., C.M.G., Deputy Chairman, British Overseas Airways Corporation.

Mr. Handel Davies, M.Sc., A.F.I.A.S., F.R.Ae.S., Director General, Scientific Research (Air), Ministry of Supply. Mr. J. Dunham, M.A., G.I.Mech.E., Grad.R.Ae.S., Research Department, Rolls-Royce Ltd.; N. E. Rowe Medallist 1959.

Sir George Edwards, C.B.E., B.Sc., Hon.F.I.A.S., F.R.Ae.S., Managing Director, Vickers-Armstrongs (Aircraft) Ltd.; Past President, Royal Aeronautical Society; Member of Council.

Mr. D. J. Farrar, M.A., F.R.Ae.S., Chief Designer (Guided Weapons), Bristol Aircraft Ltd.; British Silver Medallist 1959. Sir William Farren, C.B., M.B.E., M.A., D.Sc., F.R.S., M.I.Mech.E., Hon.F.I.A.S., Hon.F.R.Ae.S., Technical Director, A. V. Roe and Co. Ltd.; Past President, Royal Aeronautical Society; Member of Council; Honorary Fellow 1959. Mr. L. G. Frise, B.Sc., A.F.I.A.S., F.R.Ae.S., Director of Special Projects, Blackburn and General Aircraft Ltd.; Member of Council. Air Chief Marshal Sir Francis Fogarty, G.B.E., K.C.B., D.F.C., A.F.C., Chairman of the Air League of the British Empire; Director General, English Speaking Union.

Sir George Gardner, K.B.E., C.B., D.Sc., M.I.Mech.E., F.R.Ae.S., Director, Royal Aircraft Establishment; Member of Council. Mr. H. H. Gardner, B.Sc., F.R.Ae.S., Technical Director, Vickers-Armstrongs (Aircraft) Ltd.; Member of Council. Mr. S. B. Gates, O.B.E., M.A., F.R.S., F.R.Ae.S., Chief Scientific Officer and Consultant, Royal Aircraft Establishment; Honorary Fellow 1959. Colonel C. F. H. Gough, M.C., T.D., M.P., Chairman, Royal Aero Club.

Sir William Hildred, C.B., O.B.E., M.A., Director General, I.A.T.A.; Honorary Companion 1959.

Air Marshal Sir Owen Jones, K.B.E., C.B., A.F.C., B.A., D.I.C., M.I.Mech.E., F.R.Ae.S., Vice-President, Royal Aeronautical Society.

Mr. D. G. King-Hele, B.A., Guided Weapons Department, Royal Aircraft Establishment; Bronze Medallist 1959.

Mr. W. Makinson, A.F.R.Ae.S., Managing Director, Air Trainers Link Ltd. Mr. P. G. Masefield, M.A., Hon.F.I.A.S., F.R.Ae.S., Managing Director, Bristol Aircraft Ltd.; President, Royal Aeronautical Society 1959/1960. Mr. C. J. McCarthy, S.B., Hon.F.I.A.S., Chairman of the Board of Governors of the Aircraft Industries Association; Chairman of Chance Vought Aircraft Inc.: Wilbur Wright Lecturer 1959. Mr. M. B. Morgan, C.B., M.A., F.R.Ae.S., Deputy Director, Royal Aircraft Establishment; Member of Council. Dr. E. S. Moult, C.B.E., B.Sc.(Eng.), M.I.Mech.E., F.R.Ae.S., Director and Chief Engineer, de Havilland Engine Co. Ltd.; Vice-President, Royal Aeronautical Society. Professor A. J. Murphy, M.Sc., F.I.M., F.R.Ae.S., Principal, College of Aeronautics, Cranfield.

Mr. John J. Parkes, F.R.Ae.S., Chairman and Managing Director, Alvis Ltd. Colonel R. L. Preston, C.B.E., A.F.R.Ae.S., Honorary Secretary, Royal Aero Club. Captain J. L. Pritchard, C.B.E., Hon.F.I.A.S., Hon.F.R.Ae.S., Secretary, Royal Aeronautical Society 1925-1951.

Squadron Leader R. C. G. T. Rogers, D.C.Ae., A.F.R.Ae.S., R.A.F., Directorate of Fighter Aircraft, R. and D., Ministry of Supply; Member of Council. Mr. N. E. Rowe, C.B.E., B.Sc., F.C.G.I., F.I.A.S., F.R.Ae.S., Technical Director, Blackburn and General Aircraft Ltd.; Past President, Royal Aeronautical Society. Mr. A. A. Rubbra, B.Sc., M.I.Mech.E., F.R.Ae.S., Technical Director, Rolls-Royce Ltd.; Member of Council. Major General G. N. Russell, C.B., C.B.E., President, Institute of Transport.

Dr. N. H. Searby, M.I.E.E., Assistant Chief Engineer, Ferranti Ltd.; Silver Medallist 1959. Dr. C. de Stackelberg, European Representative of Chance Vought Aircraft Corporation. Mr. R. S. Stafford, C.B.E., F.R.Ae.S., Technical Director and Chief Designer, Handley Page Ltd.; British Gold Medallist 1959.

Mr. W. Tye, O.B.E., B.Sc., F.R.Ae.S., Chief Technical Officer, Air Registration Board; Member of Council.

Sir Reginald Verdon-Smith, M.A., B.C.L., Chairman and Joint Managing Director, Bristol Aeroplane Co. Ltd.

Dr. E. A. Watson, O.B.E., Hon.M.I.Mech.E., Chief Engineer, Joseph Lucas Ltd.; Silver Medallist 1959. The Hon. John Hay Whitney, Ambassador of the United States of America. Mr. L. A. Wingfield, M.C., D.F.C., A.R.Ae.S., Solicitor to the Royal Aeronautical Society. Mr. T. A. Wolstenholme, A.R.Ae.S., Group Technical Training Officer, Blackburn and General Aircraft Ltd.; Member of Council. Mr. K. A. Wood, Superintendent in Charge, Atomic Weapons Research Establishment, Orfordness; Wakefield Gold Medallist 1959.

Earth Satellites

W. H. STEPHENS, M.Sc., F.R.Ae.S.

(Director-General, Ballistic Missiles, Ministry of Supply)

The 1,100th Lecture to be given before the Society, "Earth Satellites," by W. H. Stephens, M.Sc., F.R.Ae.S., was held on 12th February 1959, at the Institution of Mechanical Engineers, Birdcage Walk, London, S.W.1, at 6 p.m. Sir Arnold Hall, M.A., F.R.S., F.R.Ae.S., President of the Society, presided. Introducing the Lecturer, Sir Arnold said that since graduating from Queen's University, Belfast, in 1935, Mr. Stephens had held distinguished posts in the scientific civil service. Joining the Aerodynamics Department of the Royal Aircraft Establishment in 1935, he went to the Ballistics Division at Woolwich in 1938 to do rocket research. From 1939-43 he was on the staff of the Director of Scientific Research at the Air Ministry and the Ministry of Aircraft Production, and then went to Washington as Assistant Director of the United Kingdom Scientific Mission and Assistant Scientific Attaché to the British Embassy. Mr. Stephens returned to the Royal Aircraft Establishment in 1947 as Superintendent, Assessment Division of the Guided Weapon Department, becoming Head of the Department in 1954, and two years later Deputy Director of the Royal Aircraft Establishment. In January 1959 Mr. Stephens was appointed Director-General of Ballistic Missiles, Ministry of Supply.

Introduction

So much has been written, both of fact and fancy, about satellites and space travel in the past few years that the selection of material suitable for presentation to the members of a learned Society concerned mainly with purely aeronautical matters is a hazardous and difficult task. I propose in this paper to tackle it by restricting the subject severely to a description of the general characteristics of near earth satellites and the scientific exploration made possible by their use as observing platforms. The later sections of the paper have a bearing on the possibilities and engineering problems of space probes and space travel; I leave it to others to speculate on the likely time scale and types of such activities and attempt instead to make sure that the basic factors involved are made reasonably clear. To set the background it is important to review briefly the actual practical achievements up to the present time.

1. Satellites Already Launched (12th February 1959)

SPUTNIK 1 (1957)

The first Russian satellite was launched in a north-easterly direction at about 21.30 G.M.T. on 4th October 1957, probably from an area some 500 miles east of the Caspian Sea. The satellite split into two main pieces on entering its orbit: an instrumented sphere 23 in. in diameter which weighed 184 lb.; and the empty structure of the rocket which had performed the last stage of propulsion.

Sputnik 1 carried two radio transmitters, operating on 20·005 and 40·002 megacycles/sec. The radio signals ceased after three weeks, when the batteries had run down. Sputnik 1 also carried instruments to measure internal temperature. Although this equipment was all inside the sphere, there were four external radio antennae, between 8 ft. and 9 ft. 6 in. long (Fig. 1). No details have been given about the size and shape of the rocket.

Initially the period of revolution of Sputnik 1 was 96·2 minutes, and its height varied between 122 and 510 nautical miles. The orbit was inclined at 65·1° to the equator. Sputnik 1 and its rocket were soon separated by the action of air drag, which affected the rocket more, because of its larger cross-sectional area. The rocket had a lifetime of 57 days, making its final descent early on 1st December 1957. The instrumented sphere lasted for about 92 days, until 4th January 1958.

The rocket was much the brighter object in the night sky, being of stellar magnitude −1 on favourable transits. The sphere was of magnitude 5 at best, and was not visible to the naked eye.

SPUTNIK 2 (1957)

The second Russian satellite was launched from the same area and in the same direction as its predecessor at about 04.30 G.M.T. on 3rd November 1957. The rocket which provided the last stage of propulsion did not separate from the instrumented section of the satellite, which was roughly conical in shape, about 7 ft. long and 4 ft. in diameter (Fig. 2). The payload totalled 1,121 lb. and included the dog Laika. The instrumentation was intended to measure solar radiation and cosmic rays, and to record the reactions of Laika, who apparently remained in good shape for several days. Sputnik 2 carried the same radio transmitters as Sputnik 1, but the signals ceased after less than a week.

Initially the period of revolution of Sputnik 2 was 103·8 minutes. Its orbit, like that of Sputnik 1, was inclined to the equator at an angle near 65° and its minimum height was also the same, 122 n. miles. But its maximum height was much greater, 900 n. miles initially. Sputnik 2 was of roughly the same brightness as the rocket of Sputnik 1. Its lifetime was 162 days and its final descent occurred just before 02.00 G.M.T. on 14th April 1958, on a line running between New York and the mouth of the Amazon (Fig. 3). The descent was widely observed from ships in the Caribbean, for the satellite was self-luminous by the time it reached New York and became more spectacular in appearance as it proceeded farther south. It had a long tail alive with sparks and took on almost every

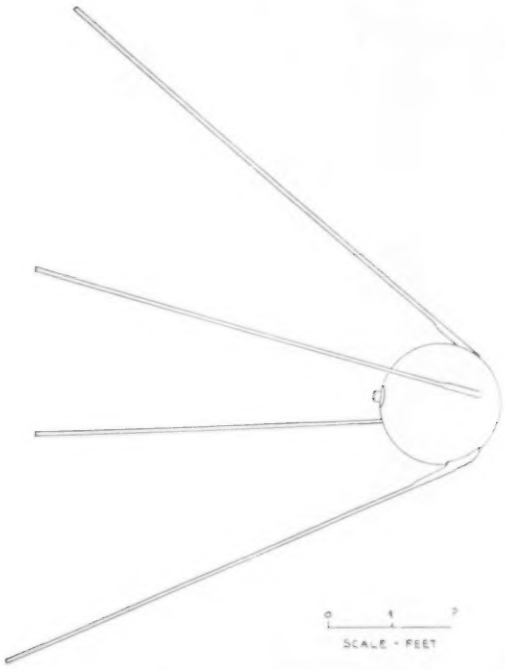


FIGURE 1. Sputnik 1.

colour of the spectrum. If any pieces of the satellite survived the descent they probably came to the earth's surface north of the equator.

EXPLORER 1 (1958)

The first successful U.S. satellite, Explorer 1, was launched in a south-easterly direction from Cape Canaveral in Florida at 03.48 G.M.T. on 1st February 1958. The satellite was propelled by a Jupiter C missile of the U.S. Army, and three clusters of solid-fuel rockets forming the second, third and fourth stages. The Jupiter C is 70 ft. long, 70 in. in diameter and weighs about 64,000 lb. Its liquid-fuel rocket motor normally burns liquid oxygen and alcohol. The solid-fuel motors were "Sergeant" motors scaled down to a diameter of 6 in. There were 11 of these in the second stage, 3 in the third stage and one in the final stage. The later stages were set spinning at a rate of 750 r.p.m. at launch, and were fired off without any control other than that provided by the spin.

Explorer 1 was cylindrical in shape, 80 in. long and 6 in. in diameter, including the empty case of the fourth-stage rocket, which remained attached to the satellite, as shown in Fig. 4. The total weight was 31 lb., of which 11 lb. was payload. Explorer 1 carried two radio transmitters, one operating on 108·03 megacycles/sec. and one on 108·00 megacycles, the former being a "high" power transmitter (0·06 watts output) and the latter low power (0·01 watts). The instrumentation of the satellite was designed to measure the intensity of cosmic rays and the impacts of micro-meteorites, as well as recording internal temperatures.

The orbit of Explorer 1 was inclined to the equator

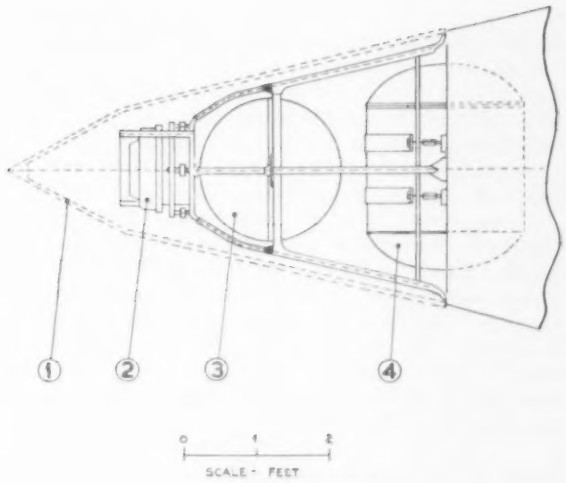


FIGURE 2. Sputnik 2.

at an angle of 33·2° and the initial period of revolution was 114·8 minutes. Initially the height was 200 n. miles at perigee and 1,370 n. miles at apogee, giving an estimated lifetime of 4 years.

VANGUARD 1 (1958)

The second U.S. satellite to be successfully placed in orbit was Vanguard 1, launched from Cape Canaveral at 12.15 G.M.T. on 17th March 1958. The satellite was a small sphere 6·4 in. in diameter, weighing 3¼ lb., Fig. 5, but it was accompanied in orbit by the empty case of the rocket which performed the last stage of propulsion, weighing 50 lb. Like Explorer 1, Vanguard 2 transmitted radio signals on 108·00 and 108·03 megacycles, but the power from transmission on the latter frequency was supplied by solar batteries.

The Vanguard launching missile, Fig. 6, has three stages of propulsion. The total weight is 22,600 lb., the length 71 ft. and the maximum diameter 45 in. The first stage has a liquid-propellant motor, burning kerosine with liquid oxygen, and is an improved version of the Viking high altitude research rocket. Control in pitch and yaw is effected by swivelling the motor. The turbine for the pumps is powered by hydrogen peroxide and the exhaust jets of steam from this system are used for roll control. The second stage is also powered by a liquid-fuel rocket, with dimethyl hydrazine and nitric acid as propellants. The second stage carries a complete control system, including three gyros to provide a reference and pitch programmer to control the angle of climb. Again, control is exercised by swivelling the motor. The third stage is a solid-fuel rocket.

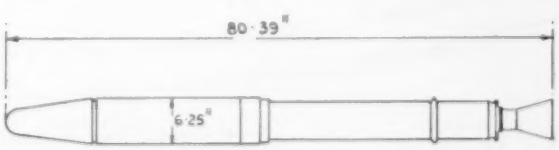


FIGURE 4. Explorers 1-4.

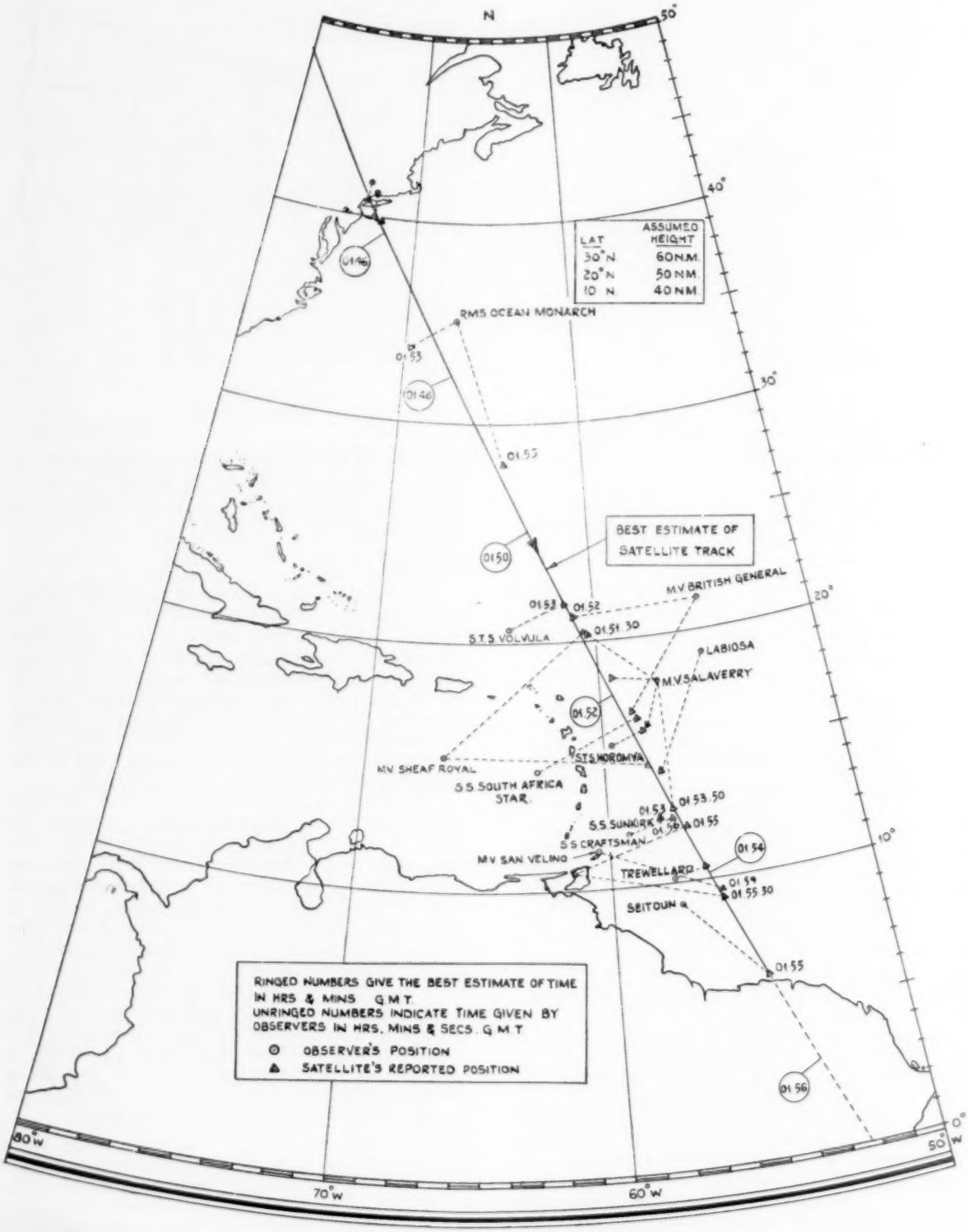


FIGURE 3. The last minutes of Sputnik 2, 14th April 1958.

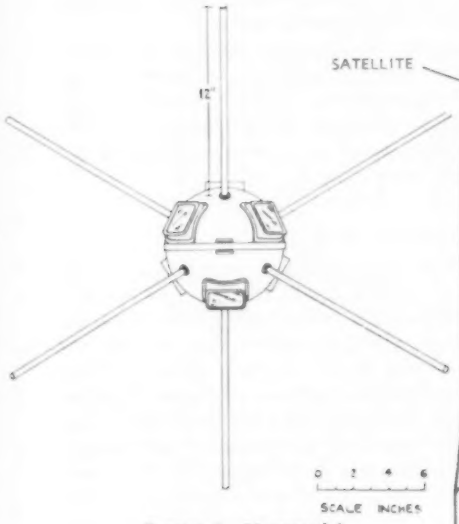


FIGURE 5. Vanguard 1.

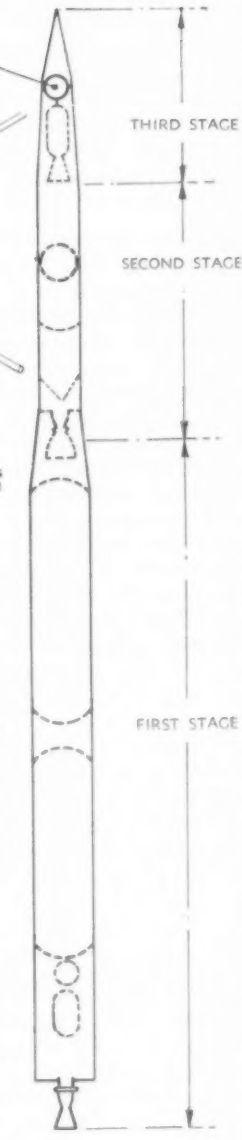


FIGURE 6 (*right*). Vanguard launching vehicle.

The orbit of Vanguard 1 is inclined at 34·3° to the equator, and the initial period of revolution was 134·1 minutes. Its height varied between 350 and 2,140 n. miles initially and, since the perigee height was so great, it is much less affected by drag than its predecessors. Its lifetime is estimated as about 100 years.

EXPLORER 3 (1958)

Explorer 2 failed to go into orbit, so the second successful Explorer is by a rather confusing nomenclature known as Explorer 3. This satellite, launched at 17.00 G.M.T. on 26th March 1958, was almost identical with Explorer 1. The main difference was that Explorer 3 carried a tape recorder, on which the readings of the instruments were stored, to be "played back" as the satellite passed over the small number of receiving stations scattered around the world. The vast majority of the information broadcast by Explorer 1 was lost because no station was near enough to pick it up, and this method of storage was obviously advantageous. Explorer 3 was designed primarily to investigate the belt of strong radiation discovered by Explorer 1.

The orbit of Explorer 3 was inclined at 33·3° to the equator, and the initial period of revolution was 115·7 minutes. The height varied between 100 and 1,510 n. miles initially and since the perigee was so low the lifetime was short, only 93 days.

SPUTNIK 3 (1958)

The third Russian satellite was launched on the morning of 15th May 1958. On entering orbit, Sputnik 3 split into five pieces, as shown in Fig. 7. The most important piece, the instrumented cone, weighed 2,926 lb. and contained 2,134 lb. of scientific instruments. It was 5·7 ft. in diameter and 9·5 ft. long, excluding aerials. The second and largest piece was the rocket which had provided the final stage of propulsion.

Sputnik 3 carried a radio transmitter on a frequency of 20·005 megacycles/sec., and the radio signals continued throughout 1958 with little diminution in strength, since their power was supplied largely by solar batteries. With its large payload, Sputnik 3 carried a wide variety of scientific instruments, measuring the pressure and composition of the atmosphere, the earth's magnetic field, cosmic rays, meteorite impacts, and temperature.

The orbit of Sputnik 3 was inclined to the equator at an angle of 65·2°, and the initial period of revolution was 105·98 minutes. The height at perigee was the same as that of Sputniks 1 and 2, 122 n. miles, but the initial apogee height was greater, 1,010 n. miles. Sputnik 3 and its rocket were initially in almost identical orbits, but drag had a much greater effect on the rocket because of its greater cross-sectional area. The lifetime of the rocket was 202 days, whereas the instrumented cone is expected to remain in orbit until December 1959.

The rocket of Sputnik 3 was clearly visible to the naked eye, being of stellar magnitude −2 on some transits. Throughout its lifetime the rocket's brightness fluctuated in a characteristic manner, with a period of between 8 and 10 seconds. The instrumented cone has been very variable in brightness, sometimes being invisible to the naked eye, sometimes giving flashes of first magnitude.

EXPLORER 4 (1958)

The fourth United States satellite, Explorer 4, was launched from Cape Canaveral at 15.00 G.M.T. on 26th July 1958. The satellite was of the same shape and size as the earlier Explorers, but weighed about 7 lb. more, with a total weight of 38·5 lb. It was launched in a north-easterly direction and its orbit was inclined to the equator at a greater angle than that of its predecessors, 50·3°. Explorer 4 was intended to measure the belt of radiation encountered by earlier

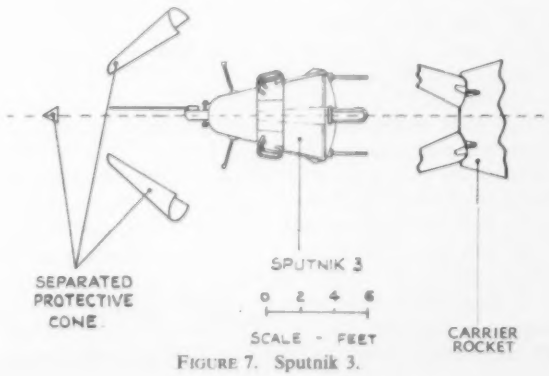


FIGURE 7. Sputnik 3.

satellites and, like them, it transmitted on 108·00 and 108·03 megacycles. Its transmitters fell silent after two months.

Initially the period of revolution of the satellite was 110·2 minutes, and its height about the earth varied between 140 and 1,190 n. miles. Its lifetime is expected to be about 13 months.

PIONEER 1

The "lunar probe" Pioneer 1 was launched from Cape Canaveral at 08.42 G.M.T. on 11th October 1958. The main propulsion, on the first stage, was provided by a Thor missile, with the second stage of the Vanguard missile (Fig. 6) as the second stage of propulsion. Pioneer 1 weighed about 80 lb., but it did not attain a high enough speed to reach the moon, and re-entered the earth's atmosphere at about 5 a.m. G.M.T. on 13th October over the South Pacific, after a flight of 44·2 hours. The trajectory of the missile is shown in Fig. 8: the apogee distance was 65,400 n. miles and the eccentricity 0·91.

Pioneer 2 was not successful; Pioneer 3, launched at 05.45 G.M.T. on 6th December 1958, followed much the same trajectory as Pioneer 1 and, like its predecessor, made useful measurements of the radiation belts surrounding the earth.

ATLAS (1958)

After Explorer 4 in July 1958, there were no further successful satellite launchings until that of Atlas at 23.02 G.M.T. on 18th December 1958. This was much larger than any previous U.S. satellite, weighing about 8,700 lb., of which only a small proportion, about 150 lb., was payload. The rest of the satellite was the empty shell of the Atlas missile which performed the launching, about 80 ft. long and 10 ft. in diameter.

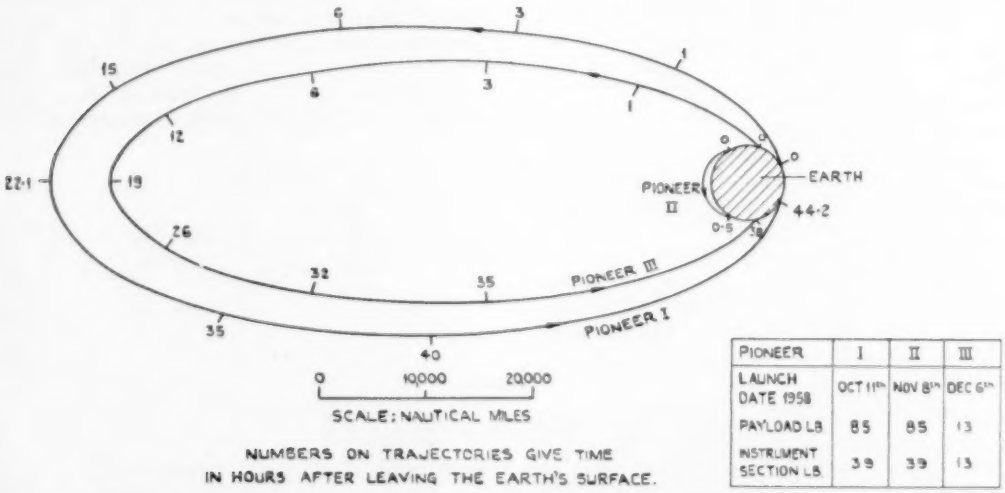
The satellite was used as a radio relay station. It stored and re-transmitted, on frequencies of 132·45 and 139·905 megacycles/sec., messages sent to it from the ground. It also carried telemetry transmitters, operating on 107·97 and 107·94 megacycles/sec.

Atlas was launched from Cape Canaveral in a south-easterly direction, and its orbit was inclined to the equator at 32·4°. Initially the period of revolution was 101·4 minutes and the height varied between 100 and 800 n. miles. Because of the low perigee height the lifetime was short, only 33 days.

THE RUSSIAN ARTIFICIAL PLANET

The final stage of a Russian multi-stage rocket, launched at about 17.00 hours G.M.T. on 2nd January 1959, flew past the moon to become the first artificial planet of the sun. The final-stage rocket is stated to have weighed 1,472 kg. (3,245 lb.) after all its fuel was burnt, and its payload of scientific instruments, together with the container, weighed 361·3 kg. (797 lb.). The instruments were intended to measure the moon's magnetic field, the intensity and composition of cosmic rays, the impact of meteors and the composition of the interplanetary gas. The rocket was also equipped with radio transmitters operating on frequencies of 183·6, 19·997, 19·995 and 19·993 Mc./s. The programme of scientific measurements is stated to have been successfully accomplished before the radio contact was lost on 5th January.

The rocket left the earth with a speed of 7 miles per sec. and when it was about 75,000 miles out, at 00·57 G.M.T. on 3rd January, it emitted a cloud of sodium vapour which was observed on earth as a glow in the constellation of Virgo. By 10.00 hours G.M.T. on 3rd January the rocket was 130,000 miles from the earth's surface, at longitude 40°W. and latitude 8°S. The rocket passed the moon, at a distance of 3,700 miles from its surface, at 02.59 G.M.T. on 4th January and was then moving at a speed of 1·5 miles per sec. away from the earth. Since the moon was near last quarter at the time of the launching the rocket's path was nearly tangential to the earth's orbit; the rocket's



PIONEER	I	II	III
LAUNCH DATE 1958	OCT 11th	NOV 8th	DEC 6th
PAYLOAD LB	85	85	13
INSTRUMENT SECTION LB	39	39	13

FIGURE 8. Trajectories of U.S. Pioneer rockets launched between October and December 1958.

orbit round the sun therefore has almost the same perihelion distance as the earth's orbit, although the aphelion distance is greater because of the rocket's greater speed at perihelion. Its orbit is inclined at only a small angle to the plane of the ecliptic and the distance from the sun is expected to vary between a minimum of 91 million miles and a maximum of 122 million miles. The period of revolution will be about 15 months, with the first perihelion on about 14th January.

2. Orbital Characteristics

We have reviewed briefly the satellites launched up to the time of writing; it has been possible only to describe their behaviour once they enter orbit, since little information has been released on the design and performance of the rockets used to launch the different satellites. If we accept this limitation for the moment, there are still a number of extremely interesting features of the orbital paths which can be deduced from theory and verified by observation.

It would of course be relatively easy to compute satellite orbits, at heights great enough for atmospheric drag to be neglected, if the earth were perfectly spherical. Motion in a central field of force would produce an ellipse, with the centre of the earth at one focus, influenced only to a minute degree by perturbations due to the gravitational effects of the sun, moon, and other bodies in the solar system. The plane and major axis of the ellipse would maintain a constant orientation in space. The real earth is however not a sphere and the atmosphere extends in tenuous fashion beyond the perigee heights of all the satellites so far launched. A good reminder of the fact that we cannot completely neglect the atmospheric drag is given by the fact that, at 200 miles altitude, there are estimated to be still about 10^9 molecules or atoms of gas in every cubic centimetre.

The flattening of the earth at the poles gives it the shape of an oblate spheroid in which the equatorial diameter is approximately 26 miles greater than the polar diameter. To help understand the effect on the orbit due to the fact that the earth's gravitational field is therefore not spherically symmetrical, it is useful to visualise a simple elliptical orbit in a plane which passes through the earth's centre and is inclined at a fixed angle α to the equator (Fig. 9). The satellite is assumed to be moving from west to east. The first effect is to cause the plane of the orbit to rotate about the earth's axis in a direction opposite to the satellite's motion, while remaining at a fixed angle to the equator. The rate of rotation, for orbits of moderate eccentricity, is approximately

$$J\sqrt{\left[\left(\frac{g}{R}\right)\left(\frac{R}{\bar{r}}\right)^{3\cdot5}\right]}\cos\alpha$$

where J is a gravitational constant which gives a measure of the oblateness, R is the earth's equatorial radius and $\bar{r}$ is the harmonic mean distance of the satellite from the centre of the earth. This formula when applied to Sputnik 1 gave a rate of 3·18°/day and this was confirmed very closely by actual observations. The variation of the rate of rotation with angle of inclination of the orbital plane to the equator is shown in Fig. 10 for several orbital heights.

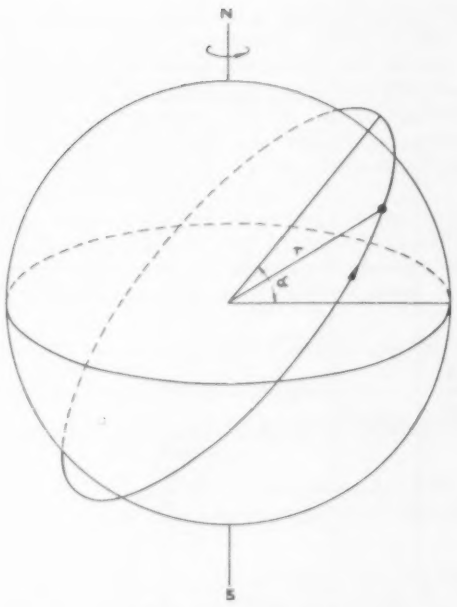


FIGURE 9. Satellite orbit.

The second main effect of oblateness is to cause the major axis of the orbital ellipse to rotate slowly in the orbital plane. The rotation is in the same direction as the satellite for near-equatorial orbits and backwards for polar orbits. The rate of rotation is given by

$$\frac{J}{2}\sqrt{\left[\left(\frac{g}{R}\right)\left(\frac{R}{\bar{r}}\right)^{3\cdot5}\right]}(5\cos^2\alpha-1)$$

and is shown in Fig. 11. The Sputnik orbits were in a plane inclined at about 65° to the equator and so the rate of rotation was very slow, fortunately for those who were trying to establish their orbits from early and somewhat inaccurate observations.

Finally a third small perturbation exists in the form of a periodic departure from a true ellipse, with a period equal to half the orbital period of the satellite. The full theoretical investigation of these effects was given by King-Hele[1].

In addition to these gravitational effects, the orbital motion is also influenced by atmospheric drag. Unlike the gravitational effects, which do not alter the general shape of the orbital ellipse, but only its orientation in space, the main effect of the atmosphere is to distort the ellipse, while leaving the orientation relatively unchanged. If we consider a satellite on a non-circular orbit, the retardation due to air drag varies during each revolution since the exponential density variation of the atmosphere causes the drag at perigee to be very much greater than that at apogee. Each time the satellite passes through perigee it loses momentum and so is unable to swing out so far at the subsequent apogee; the apogee height thus decreases quite rapidly and the

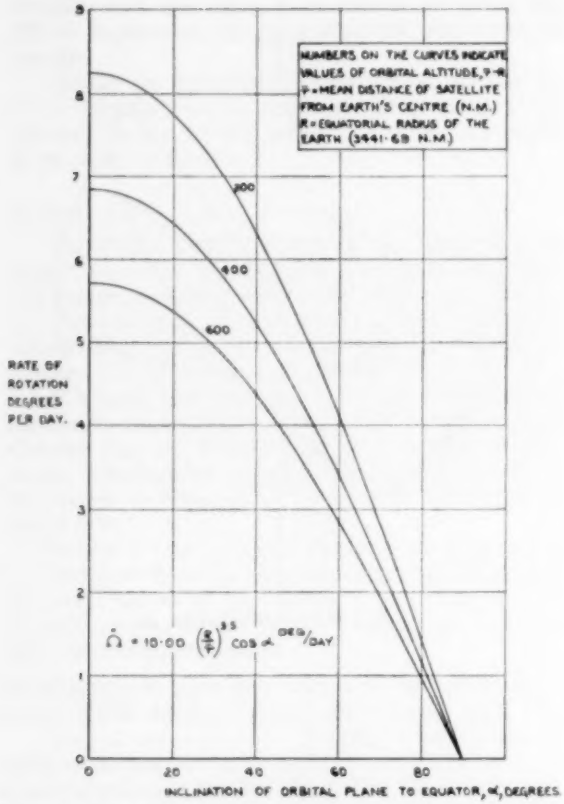

NUMBERS ON THE CURVES INDICATE VALUES OF ORBITAL ALTITUDE, $\bar{r}$-R
$\bar{r}$ = MEAN DISTANCE OF SATELLITE FROM EARTH'S CENTRE (N.M.)
R = EQUATORIAL RADIUS OF THE EARTH (3441·69 N.M.)
200
400
600
RATE OF ROTATION DEGREES PER DAY.
$\dot{\Omega} = 10{\cdot}00 \left(\frac{R}{\bar{r}}\right)^{3.5} \cos\alpha$ DEG/DAY
INCLINATION OF ORBITAL PLANE TO EQUATOR, α, DEGREES

FIGURE 10. Rate of rotation of the orbital plane about the earth's axis.

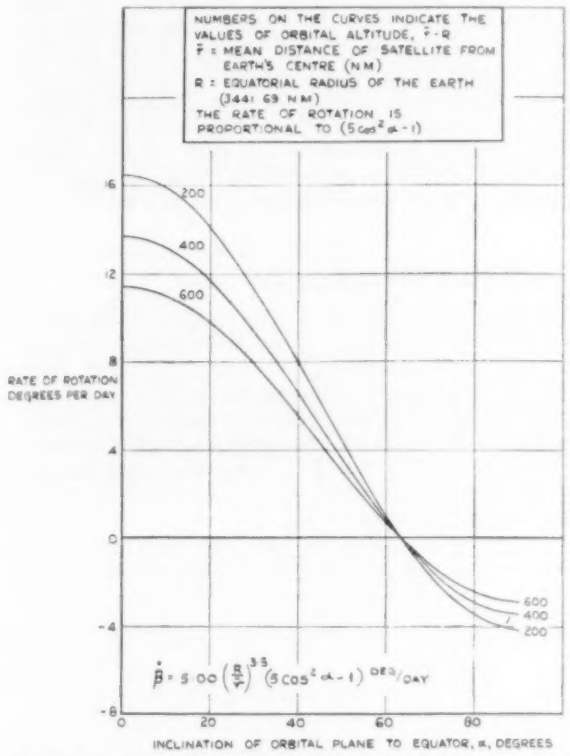

NUMBERS ON THE CURVES INDICATE THE VALUES OF ORBITAL ALTITUDE, $\bar{r}$-R
$\bar{r}$ = MEAN DISTANCE OF SATELLITE FROM EARTH'S CENTRE (N.M.)
R = EQUATORIAL RADIUS OF THE EARTH (3441·69 N.M.)
THE RATE OF ROTATION IS PROPORTIONAL TO $(5\cos^2\alpha - 1)$
200
400
600
RATE OF ROTATION DEGREES PER DAY
$\dot{\beta} = 5{\cdot}00 \left(\frac{R}{\bar{r}}\right)^{3.5} (5\cos^2\alpha - 1)$ DEG/DAY
INCLINATION OF ORBITAL PLANE TO EQUATOR, α, DEGREES

FIGURE 11. Rate of rotation of major axis of orbit, measured in the orbital plane.

orbit becomes less eccentric, but the perigee height suffers very little change. The period of revolution decreases because the average height in the orbit is being reduced. Two easily observable effects are thus produced by atmospheric drag, reduction in apogee height and in orbital period. Both were measured for the Sputniks and Fig. 12 shows the change in apogee and perigee heights during the lifetime of Sputnik 2; the decay in orbital period followed a pattern similar to that of the apogee height.

Once the orbit becomes nearly circular, the drag is nearly constant and its effect is to convert the circle into a spiral. The first sign that a circular orbit is beginning to be affected by air drag is a decrease in orbital period and an increase in the speed in the orbit. The latter otherwise puzzling effect arises from the fact that, although an increase in speed infers an increase in kinetic energy, this is more than balanced by a loss in potential energy due to the loss in height, giving a net loss of energy which is used up in overcoming the air resistance.

If we assume a uniform spherical earth and a circular orbit at distance r from the earth's centre, the velocity in the orbit is given by

$$\frac{v^2}{r} = g\frac{R^2}{r^2}$$

where R = earth's radius. If the height decreases by a small amount Δr in one revolution, the gain in kinetic energy is

$$\tfrac{1}{2}mgR^2\left(\frac{1}{r-\Delta r} - \frac{1}{r}\right) \simeq \tfrac{1}{2}mv^2\frac{\Delta r}{r}$$

where m is the mass of the satellite. The loss of potential energy is

$$m \,.\, g\frac{R^2}{r^2} \,.\, \Delta r = mv^2\frac{\Delta r}{r}$$

and this is twice the gain in kinetic energy.

The difference is the work done against the drag force F, assumed constant around the orbit. We then have

$$\tfrac{1}{2}mv^2\frac{\Delta r}{r} = 2\pi rF$$

If we write

$$F = \tfrac{1}{2}\rho v^2 SC_D$$

where

ρ = air density
S = frontal area
C_D = drag coefficient

then

$$\frac{\Delta r}{r} = 2\pi r\rho\frac{SC_D}{m}$$

but $\frac{\Delta r}{r}$ can be obtained from the change in orbital

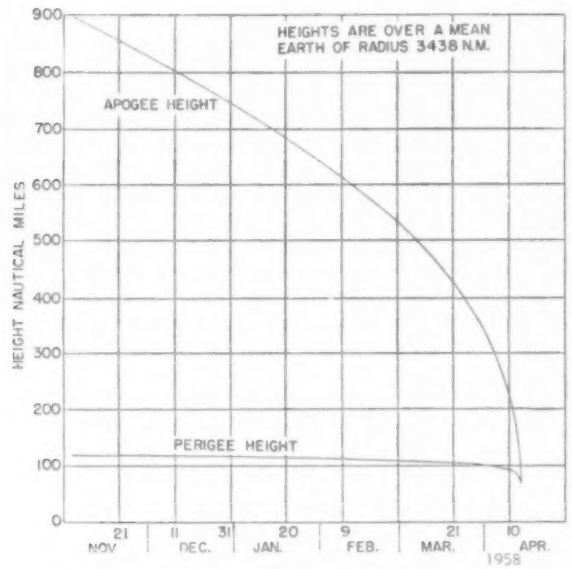


FIGURE 12. Apogee and perigee heights for Sputnik 2.

period which can be observed quite accurately, using the relation $T = 2\pi r/v = \frac{2\pi}{Rg^{\frac{1}{2}}} \cdot r^{3/2}$ from which

$$\frac{\Delta T}{T} = \frac{3}{2}\frac{\Delta r}{r}.$$

If then SC_D/m can be estimated, the value of ρ can be deduced. As mentioned later in Section 4 the observed behaviour of Sputnik 3 suggested considerable variation either in drag coefficient and effective cross section area, or in the actual values of air density. This Sputnik showed marked fluctuations in brightness on most transits which suggested that tumbling was occurring and causing changes in effective presented area, although the mean presented area was probably reasonably constant.

3. Launching and Propulsion

The geometric characteristics of the orbits listed in Section 1 and the perturbations of those just described vary widely, but the orbits all have one property in common, namely, a satellite velocity enormous by earthly standards; although quite modest in comparison with the velocities in space of various planets in the solar system. It is quite simple to obtain a rough idea of the velocity required if we assume no air resistance and visualise the satellite as a body projected horizontally from a high mountain. After one second gravity will cause a drop of 16 ft. and if the body is still at the same height above the earth's surface it will circle the earth as a satellite. Now the distance moved in this first second must in fact be the distance of the horizon as seen from a height of 16 ft. From the usual formula d (miles) $= 1{\cdot}22\sqrt{}$(height in ft.) we see that about 5 miles per second is the required orbital velocity.

To achieve speeds of this order we must turn to rocket propulsion, since only by this means can we continue to produce accelerating thrust at the great heights where air resistance is low enough to allow sustained flight at hypersonic speed and the eventual achievement of orbital velocity. It is therefore of interest to examine the main design parameters of possible launching rockets and the problems of guiding them into desired orbits.

The range attainable by a single stage rocket is roughly proportional to the square of the all-burnt velocity. This in turn is a function of the exit velocity of the rocket gases and can be expressed as

$$V = V_E \log \lambda - V_1 - V_2$$

where V_E = exit velocity of the gases

λ = total weight at launch divided by weight at all-burnt

V_1, V_2 = velocity losses due to gravity and drag: for a given trajectory they can be regarded as constant.

V_E is related to the specific impulse; for a typical S.I. of 250, $V_E = 8{,}000$ ft./sec. Given particular values of S.I., the parameter λ then determines the performance obtainable and Fig. 13 shows the impact ranges attainable with a single stage missile, for various values of S.I., as a function of λ.

From the viewpoint of payload carrying capacity, a useful parameter is the payload ratio W = total weight at launch divided by payload weight. With this is connected another most important parameter ξ, which gives a measure of the structural efficiency of the rocket. ξ is defined as weight of usable propellant divided by total weight of stage (less payload). Obviously W should be low and ξ close to unity for an efficient design. The relation between the three parameters is

$$1 - \frac{1}{W} = \frac{1}{\xi}\left(1 - \frac{1}{\lambda}\right)$$

and is illustrated in Fig. 14 for several values of ξ. If we remember that a range of 10,800 miles is halfway round the earth and so almost equivalent to a near satellite orbit, the value of λ required for this range, assuming a specific impulse of 250, is given from Fig. 13 as 30. It is then clear from Fig. 14 that a payload ratio W below 100 can only be achieved if ξ exceeds 0·98; such an efficiency is impractical with any available structural materials.

If we assume a structure consisting of a thin cylindrical shell, divided internally into two compartments for fuel and oxidant, and stabilised by pressure to keep the skin always in tension, then the following weight breakdown might be estimated for rockets with total propellant weights in the range 100,000 lb. and above: —

Structure weight	2½ per cent of propellant weight
Engine weight	2 ,, ,, ,,
Controls and unburnt propellant	1½ ,, ,, ,,

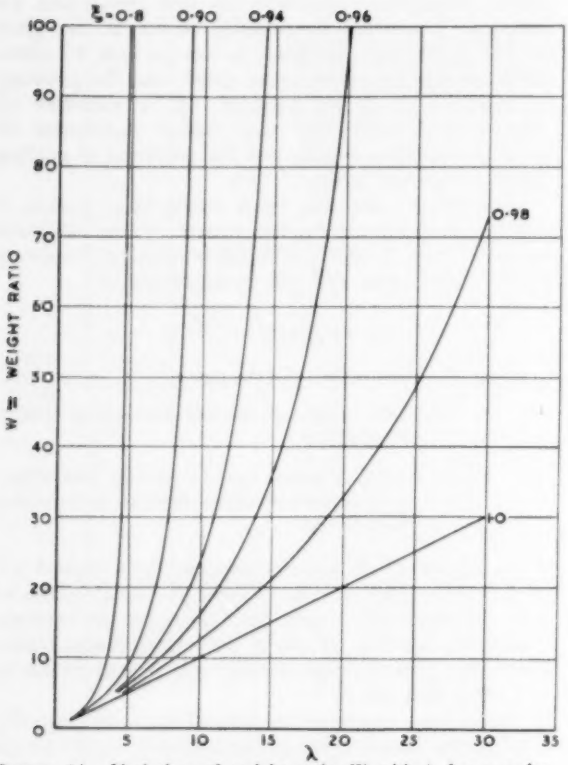


FIGURE 14. Variation of weight ratio W with λ for a series of values of ξ.

The value of ξ should thus be close to 0·94, and from Fig. 14 we can deduce that the mass-ratio λ must be kept down to less than 15 before a practical payload can be carried. Fig. 13 then shows that, unless a specific impulse greater than 320 can be realised, there is no hope of launching a satellite with a single stage rocket. In fact that practical value of ξ also depends heavily on the mean propellant density in the way illustrated in Fig. 15. The high S.I. can be obtained from propellant combinations such as liquid oxygen and liquid hydrogen, but the structural efficiency may be expected to fall off. The density of liquid hydrogen is 0·07 gm./cc. and so the mean density of a 5 : 1 mixture by weight of $O_2 : H_2$, which gives a theoretical sea level S.I. of 330, is only 0·33 gm./cc. For this density ξ is likely to be approximately 0·88 and from Fig. 14, with $\lambda = 12-15$, the payload ratio W is obviously infinite; so no practical solution is possible.

Thus for significant satellite weights, using fuels with S.I. below the above figure, we must turn to the use of staging, *i.e.* discarding *en route* the useless inertia of such parts as empty fuel tanks. If we assume two stages of propulsion, with a configuration of the type shown in Fig. 16 and further assume the same initial/all-burnt mass ratio for each stage, then Fig. 17 shows the impact range attainable as a function of λ. For $I_0 = 250$ the half earth circumference range is now attainable with $\lambda = 5{\cdot}5$, while $I_0 = 350$ allows this to reduce still further to 3·5.

If we assume a first stage sea level S.I. of 250 and a second stage using propellants capable of giving a

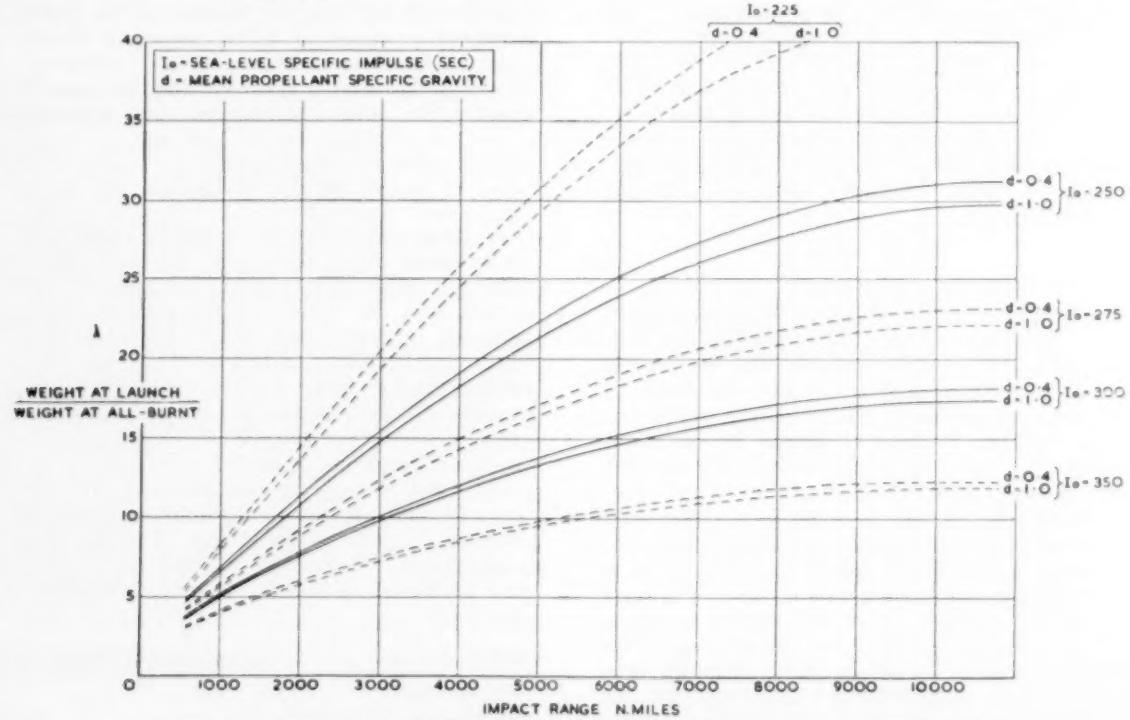


FIGURE 13. Variation of initial/all-burnt weight ratio λ with impact range for missiles with one stage of propulsion.

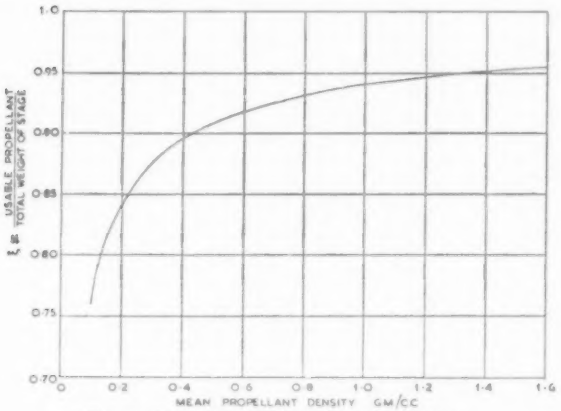


FIGURE 15. The variation of ξ with density.

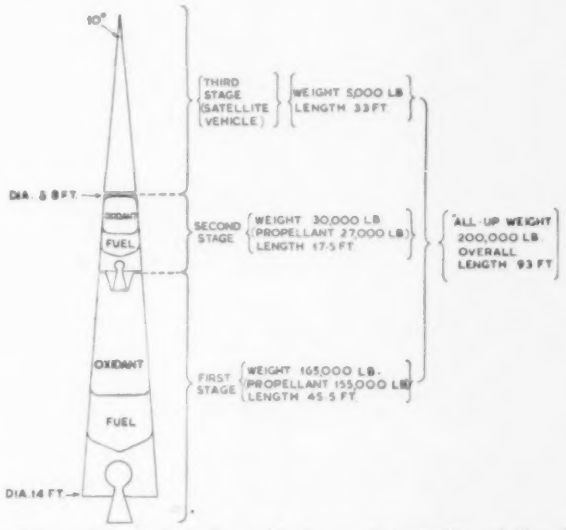


FIGURE 16. Sketch of possible layout for satellite missile of 200,000 lb. weight at launch.

sea level S.I. of 300, then a rocket of roughly 200,000 lb. A.U.W. can project into near orbit a satellite of about 5,000 lb. The weights and dimensions of such a two-stage combination might be approximately as shown in Fig. 16.

Turning now to nuclear propulsion, it is clear that the dead weight of the reactor is likely to limit the application of this form of power plant to the larger satellites, since otherwise the high S.I.s produced are more than counterbalanced by the poor ratios of initial to all-burnt weight achievable. Another factor which also increases the difficulty of achieving high structural efficiency in a nuclear rocket is the very low density of liquid hydrogen which, because of its low molecular weight, is otherwise a very desirable working fluid. The variation of λ with range is shown in Fig. 18 for several values of the mean propellant density and S.I.s at sea level of 500, 750 and 1,000. Fig. 19 then shows the values of the weight ratio W attainable as a function of range, based on the λ's from Fig. 18, for S.I.s of 500, 750 and 1,000 and a propellant density of 0·07, that of liquid hydrogen, and a reactor weight of four

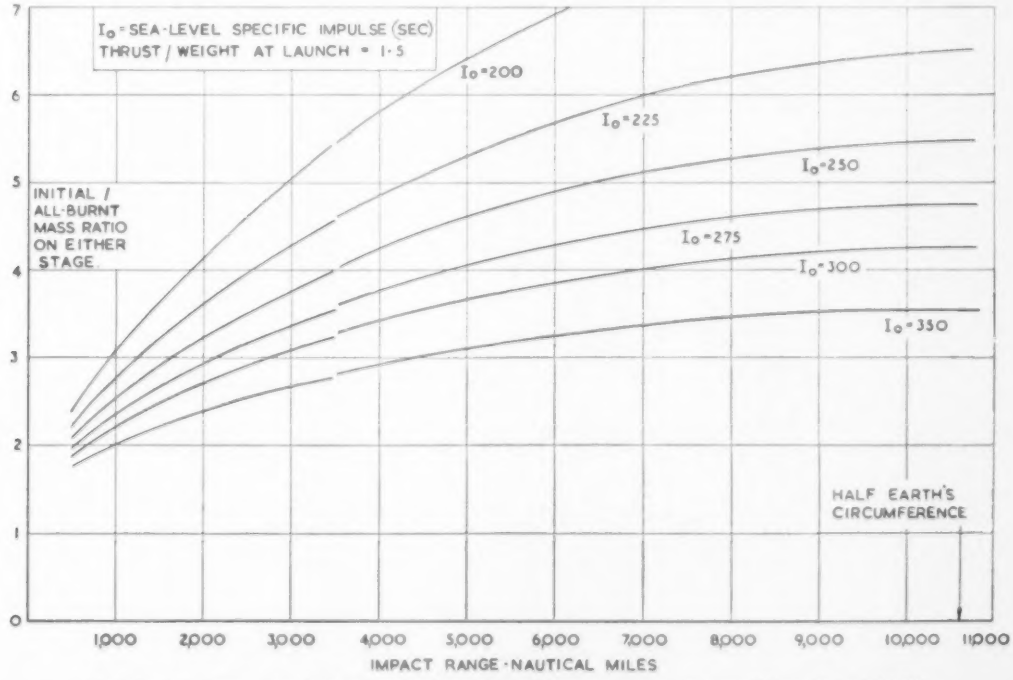


FIGURE 17. Range attained by ballistic rockets with two stages of propulsion when initial/all-burnt mass ratio is the same on both stages.

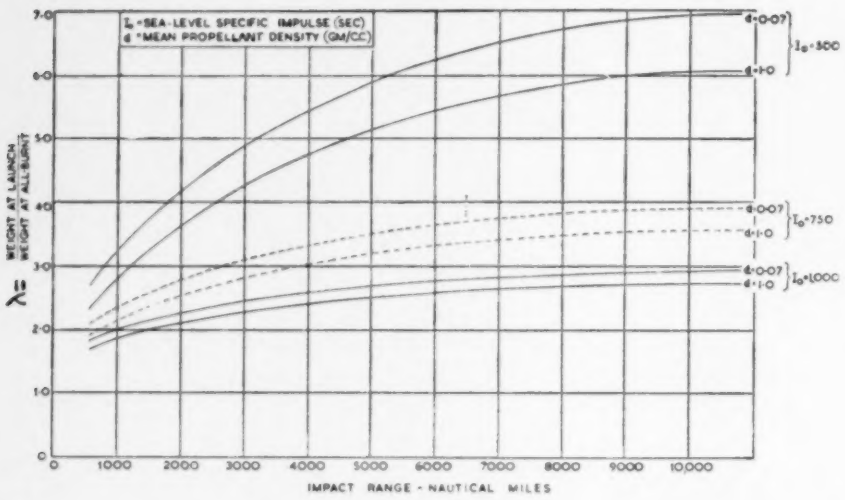


FIGURE 18. Variation of initial/all-burnt weight ratio λ with impact range for one-stage missiles with specific impulses between 500 and 1,000.

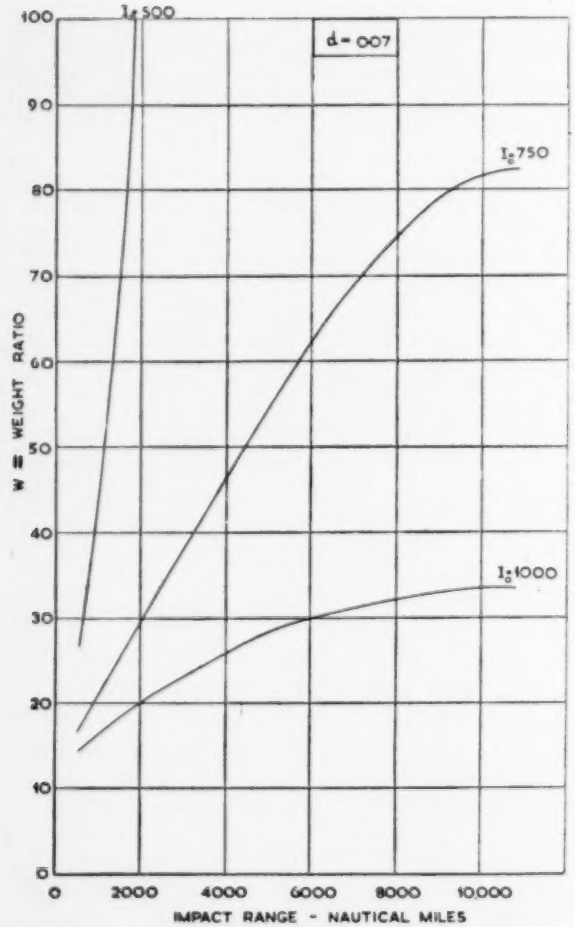


FIGURE 19. Variation of weight ratio with impact range for missiles powered by nuclear rockets.

times the payload. For a range of 10,800 miles, roughly equivalent to a satellite orbit, a sea level S.I. of not less than about 700 is obviously needed. According to Shepherd[2] a reactor using hydrogen as the working fluid and operating at a chamber temperature of 2,800°K and 300 p.s.i.a., should give a sea level S.I. of 800 sec. We might expect, therefore, to be able to launch about a 2 ton satellite into orbit from an initial weight of 130 tons with a single stage nuclear rocket. Whether the additional cost and possible radiation hazard would be worthwhile in this size bracket seems doubtful.

In very much larger satellites, the high specific impulse promised by nuclear propulsion units would appear to make them attractive, and Shepherd (*loc. cit*) estimates a 1,000 ton launching weight for a 60 ton payload. There will no doubt be many problems of reactor materials and structural design to solve before we have a satisfactory power unit, capable of withstanding prolonged acceleration and the extremely high operating temperatures necessary for high efficiency, and at the same time staying within acceptable limits of radio-active and toxicity safety. There will also be problems of rocket airframe design associated with the very low temperature of liquid hydrogen, if this is used as the propellant, and with the stressing of the large tanks required to carry it.

4. Navigation and Control

Before we can make practical use of the propulsion and structural design possibilities to launch instrument or human payloads into chosen paths around the earth, or between the earth and neighbouring planets, we have to solve the navigation problem. Essentially this reduces to the provision of means to determine precisely the vector velocity required at any point to achieve a desired destination, and of the vector acceleration necessary to make navigational corrections as soon as any errors in velocity are noticed. If we take a three-stage vehicle as example, Fig. 20 shows a typical boost plan and subsequent acceleration to orbital speed for a

simple near circular orbit. The velocity and position of the missile at cut-off of the second stage decide the velocity and position of the third stage when it reaches maximum altitude. At this altitude the increment in velocity required to reach orbital condition is provided by the third stage motor. Obviously the direction or magnitude of this velocity increment will control the extent to which the orbit differs from a circular orbit. Assuming that a circular orbit is the desired path, Fig. 21 shows the effects of errors in magnitude and direction of the final velocity.

In most of the satellites so far launched no attempt has been made to control precisely the duration of the final thrust, and the tendency has been to give an excess of thrust so as to ensure that an orbit can be achieved despite errors in direction of the final acceleration. The result has been to produce apogee higher than perigee. In the Explorer satellites, which were four-stage vehicles, the velocity and position at first stage burn-out were determined by ground observation. The time to reach the apex of the coasting trajectory was then computed and firing of the final motor stages was started by radio command from the ground just before reaching apex. The direction of the final thrust was controlled by auto-pilot, which tilted the final stage by air jets to align their axis along the local horizontal at the apex point. By this means complexity in the final stages of the vehicle was held to a reasonable level, but the method would be subject to considerable errors if a precisely defined circular orbit was an important objective.

For many scientific investigations and especially for reconnaissance and astronomical satellites, it would be necessary to stabilise the satellite (or equipment in it) to a known orientation. The satellite might be stabilised approximately (to a few degrees) and the equipment accurately (to a few minutes of arc). In addition the orientation of the satellite must be referred to a system of axes, which might be fixed in space, relative to the earth or relative to a line joining the satellite to the centre of the earth. Such a satellite referred to space axes would make one rotation during each orbit of the earth. In a similar manner a satellite stabilised with one axis pointing to the sun would make one rotation each year when referred to space axes, *i.e.* approximately one degree per day rotation.

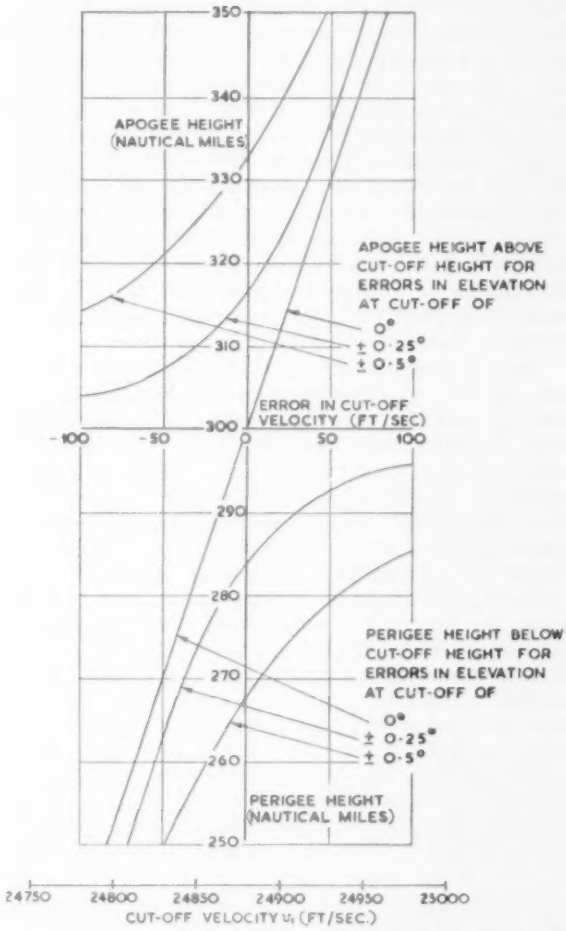


FIGURE 21. The effect of errors at cut-off on a near circular satellite orbit.

The problems of control using reaction thrust from gas nozzles are an interesting subject for investigation.

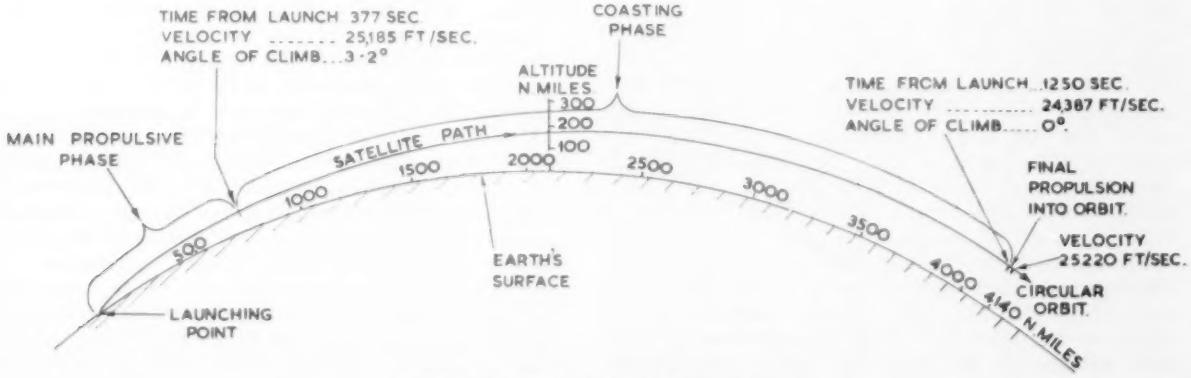


FIGURE 20. Typical satellite climb path.

The energy required can be stored as compressed air or, chemically, as one of the monofuels such as hydrogen peroxide or isopropyl nitrate. The latter will result in less weight but would only be suitable for use within a reasonable time of launch. They could certainly be used for removing any large angular momentum produced at the termination of thrust. After this it would probably be preferable to use a method depending on the conservation of angular momentum. In addition, rates of rotation could be reduced by means of the translation of masses away from the centre of gravity of the satellite (*i.e.* a change in moment of inertia). The engineering problems to produce accurate control would appear to present no insuperable difficulties.

Provision of the reference system may prove more difficult. For space stabilisation the fixed stars are an obvious choice. However, it would be necessary to lock on to two stars prior to launch. In addition, eclipse of these stars by the earth would necessitate a subsidiary system. Thus it would appear necessary to have a gyro-stabilised platform with the star tracking system mounted on it. During the eclipse of the stars the drift of the platform must be small in order that the optical system locks on to the same stars when they come into view. This requirement would specify the accuracy of the stable platform and gyroscopes. Given such a system the best results would be achieved by a suitable combination of the outputs of the optical system and the gyroscopes. The theoretical background to make optimum use of a mixed system of this type is well understood. It is evident that having gone this far, it might be reasonable to include three accelerometers, mounted orthogonally on the stable platform, to give a complete inertial navigator. Such a system could then be used in the boost phase of satellite launching for guidance. In addition it could be used to control the direction and magnitude of final thrust.

5. The Measurements possible from Satellites

Having examined practical ways and means of projecting quite large payloads into orbit, for what purposes are we likely to use it? The answer depends on the variety of scientific measurements made possible by having the observing platform outside most of the blanket of atmosphere which very effectively prevents us from receiving directly on the ground more than a minute fraction of the electromagnetic and particle radiation falling upon the fringes of our atmosphere. Fig. 22 shows the selective transmission properties of the atmosphere, which allow only a narrow band in the visible spectrum, and a fraction of the radio band to penetrate to the earth's surface. The radiation which is probably pouring upon the outer fringes of the atmosphere throughout the rest of the frequency spectrum is either absorbed or reflected. In particular the ultra-violet and X-radiations from the sun are absorbed in the high atmosphere and hitherto have been seen only during brief rocket ascents. The sun's radiation determines, to mention only two important phenomena, the heat balance of the earth and hence our climatic environment, and the properties of the ionosphere

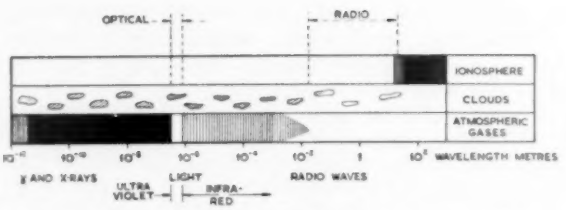


FIGURE 22. The obstruction offered by the atmosphere to electromagnetic waves, showing the optical and radio windows (from *Radio Astronomy* by Pawsey and Bracewell).

which, in turn, influence long range radio communications. The deeper understanding of the physics of the sun as a radiating star and of the character and intensity of the radiation must, therefore, improve our knowledge and understanding of our environment; continuous observation of the sun's ultra-violet and X-radiation from a vantage point outside the absorbing layer is of the utmost interest. Already, for example, a few short duration measurements made by rockets have shown large variations in intensity of the short wavelength radiation, even during periods of low sunspot activity.

In addition to studies of radiation from the sun, satellites offer the possibility of astronomical observations in the ultra-violet and infra-red, and should thereby elucidate some of the fundamental atomic reactions occurring in space, which have previously been veiled from us by clouds of interstellar dust and by our own atmosphere. X-ray and gamma-ray measurements, together with observations in the longer wavelength region of the spectrum are expected to yield new information on the nature of the sources of such radiations and thence on the basic properties of our galaxy and the Universe.

Other important effects occur in the atmosphere itself, which again throw light on the fundamental phenomena from which they spring. Thus the primary cosmic rays, which are largely of unknown origin, fall upon the upper atmosphere where they produce secondary particles, often in showers, in which whole families of new fundamental particles have been identified. The energy of the primary cosmic particles, which seem to consist of atomic nuclei of hydrogen, with some helium and heavier atoms, is as much as 10 million times greater than we can produce in the laboratory, even with the biggest atom smashing machines and particle accelerators. These primary particles can penetrate up to 40 in. of lead and the sources which generate them must be extremely potent. On the average each person at ground level is penetrated by about four cosmic particles per minute. Study of cosmic radiation has already had a profound influence on theoretical concepts of the basic structure of matter; measurements by satellites above the atmosphere should yield further valuable information by giving observations on the primaries before interaction with atmospheric atoms, by continuous observations of greater statistical value and by showing the pattern of the radiation as a function of the magnetic field in the space around the earth and moon. It should also be

possible to use the high energy primary cosmic rays to conduct nuclear experiments for which ground facilities are inadequate.

Another whole class of experiments can be performed without any special instrumentation in the satellite but simply by careful observation of the orbit and its behaviour with time. Observation of the satellite in orbit can be made either by radio or optical means. If the satellite transmits on suitable frequencies in the megacycle range its path can be plotted by radio interferometers or Doppler methods. These methods have the advantage that, in the early stages of its life, the satellite can be located without previous information on the likely orbit, since the transmitters announce its position over a wide area of reception. The orbits of the first Sputniks were established by such radio means.[3, 4] Once the transmission ceases, only optical methods can be used and these have played a major part in establishing accurate orbits for those satellites which have been visible to the naked eye, such as Sputniks 2 and 3. The kiné-theodolite has proved invaluable for accurate optical observations and was used at various outstations of the Royal Aircraft Establishment, Fig. 23. Under good conditions an accuracy of 20 seconds of arc was achieved.

FIGURE 23. Kiné-theodolite sites.

Several interesting proposals have been put forward for tracking satellites against star backgrounds and for observation of faint satellites. For the latter purpose Willmore[5] has developed a photo-electric method which may have application to automatic optical following. The most difficult problem is that of searching for lost satellites, particularly those below naked eye visual threshold. In attempting to mechanise this process there is an obvious clash between the wide field of view needed for search and the high sensitivity needed to pick up faint objects against noise due to general background light.

By various means accurate orbit observations have proved possible and, as mentioned in Section 2, the earth's gravitational characteristics can then be deduced from the orbital precession. Secondly, by simultaneous precise observation of the satellite from several points on the earth, the location of these points relative to one another can be obtained more accurately than has been possible by the conventional methods of geodesy. Perhaps in the future, the satellite method may be extended to give information on continental drift or movements of the earth's crust. Finally, the density of the high atmosphere can be deduced from the life history of near satellites.

6. Ionospheric Measurements

Worldwide radio observations have been made which will provide much valuable information on ionospheric conditions. A particular method of measurement of electron density in the ionosphere has been developed by the Royal Aircraft Establishment, which very elegantly uses the effect of Faraday rotation. This is the rotation of the plane of polarisation of electromagnetic waves due to the effect of a magnetic field on the refractive index of the medium through which they are transmitted. In the ionosphere the refractive index is determined by the content of free electrons, and a measurement of the polarisation of the signal from a satellite transmitter gives a measure of the vector product of the earth's magnetic field and the total electron content along the path from observer to satellite. The difficulty lies in determining the datum from which to count the rotations, and this is resolved if observations can include a point in the orbit at which the earth's field in the ionosphere is perpendicular to the propagation direction. At this point there is no rotation and in passing through this region the direction of rotation will reverse. The orbit of Sputnik 3 is such that this null point is well above the horizon for observations from Malta. The radio measurements are simple, and consist in recording signals on orthogonal aerials and inspecting the fading pattern. This pattern is complicated by the spin and tumbling of the satellite, but these can be resolved by the fact that the genuine Faraday rotation fades occur in time quadrature on the orthogonal aerials. Successful records were obtained at Malta during the past few months and results will shortly be published.

7. Scientific Results from Satellite Measurements

7.1. THE SHAPE OF THE EARTH

In the past the flattening of the earth at the poles has been determined by a number of different methods, none of them entirely satisfactory. The two main methods were, first, gravity measurements, which, when corrected for the earth's rotation, give a picture of the earth's gravitational field and hence its shape; and, second, measurement of arcs over the earth's surface, which, when compared with astronomical determinations of latitude, show the variation in the length of a degree of latitude over the globe. Both these methods are hampered by local irregularities such as mountains and, until recently, both were confined to measurements on land. The flattening could also be determined by measuring the precession of the earth's axis, which is caused by the gravitational pull of the sun and moon on the earth's equatorial bulge, and from certain perturbations to the moon's orbit. The precession method, however, requires some unproved assumptions about the distribution of mass in the earth, and the perturbations to the moon's orbit have to be separated from numerous other perturbations.

The main effect of the earth's oblateness on a satellite orbit is, as has already been explained, to rotate the plane of the orbit about the earth's axis. The rate of rotation can be expressed theoretically in terms of the flattening and, since the rate of rotation can be measured very accurately from observations, a more accurate value of the flattening is obtainable. The flattening f is defined as the difference between the equatorial and polar radii of the earth, divided by the equatorial radius,

$$f = \frac{R_E - R_P}{R_E}$$

Before the satellite launchings the value generally accepted for f in Britain and the United States was $f = \frac{1}{297 \cdot 1}$. Results from the satellites[6] suggest the value $f = \frac{1}{298 \cdot 2 \pm 0 \cdot 1}$. This implies that the flattening at the poles is 250 ft. less than was previously supposed.

There are other perturbations to satellite orbits which will yield geodetic information. For example any asymmetry of the earth about the equator will slowly change the inclination of the orbit to the equator. With most of the satellites so far launched the greater part of the change in inclination has been caused by the lateral aerodynamic forces due to the rotation of the atmosphere, and it has not been possible to separate the smaller effects caused by asymmetry of the earth, but measurements on the long-lived Vanguard 1, which is scarcely affected by air drag, should determine the asymmetry.

7.2. AIR DENSITY AT HIGH ALTITUDES

Direct measurements of air density from high-altitude rockets have been subject to considerable uncertainty because gases exuding from the surface of the rocket may contribute to the measured values of density. It is in many ways preferable to have an indirect method of determining density, for example from drag measurements; and the contraction of a satellite orbit under the action of drag offers an excellent opportunity for this approach.

A satellite is affected most by drag when it is nearest to the earth, at perigee, but the effect of drag is appreciable over quite a wide arc near perigee. The integrated effect of this drag determines how much the orbit will contract and how much the period of revolution will change. So the observed rate of change of period only gives a value of density at perigee if the rate of change of density with height is known. If the effective drag cross-sectional area of a satellite is S and its mass m, the density at pergiee, ρ_p, is given by

$$\rho_p = \left(-\frac{dT}{dt}\right) \frac{m}{3SC_D} \sqrt{\left(\frac{2e}{\pi aH}\right)}$$

if the orbital eccentricity e is small. In this equation a

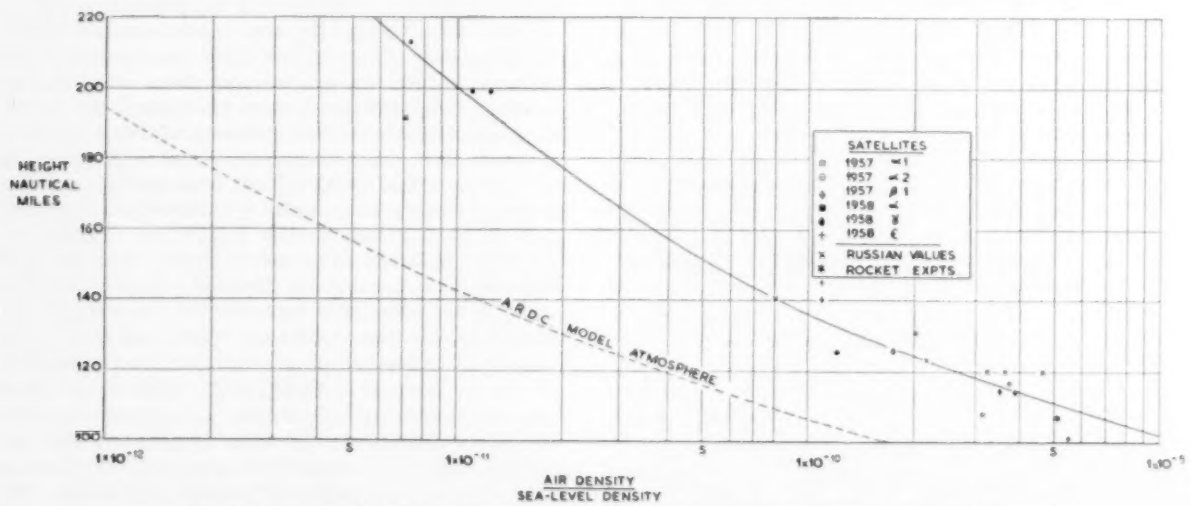


FIGURE 24. Variation of air density with height: comparison of satellite results with A.R.D.C. atmosphere.

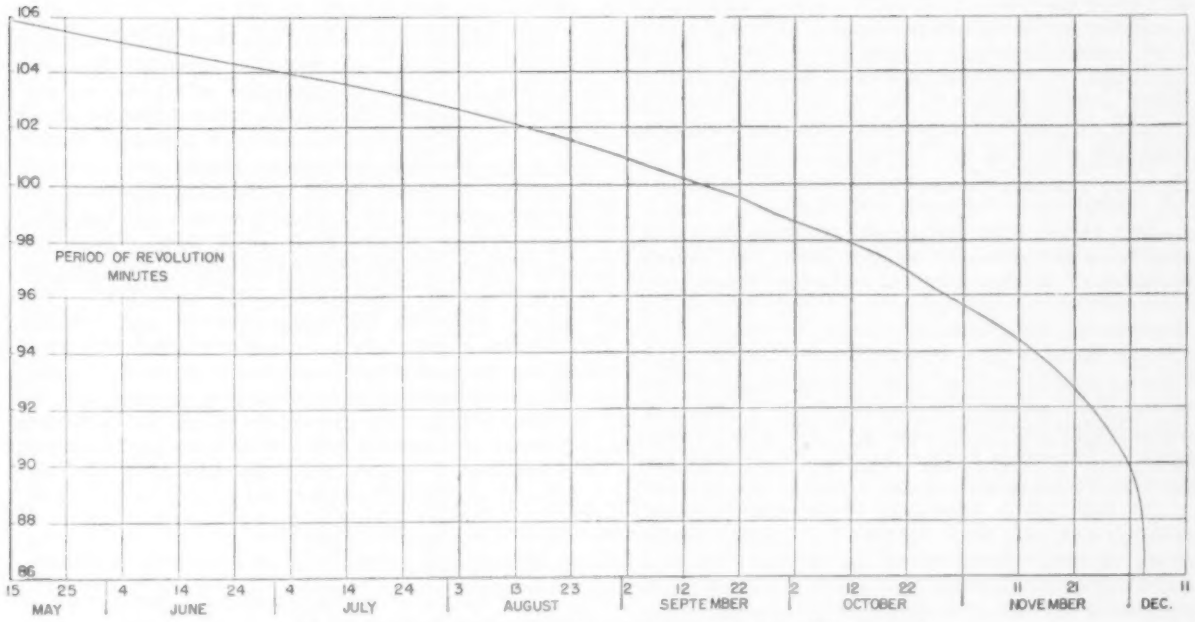


FIGURE 25. Period of revolution of Sputnik 3 rocket (1958 Section 1).

is the semi-major axis of the orbit and H is the scale height of the atmosphere at perigee altitude. H can be determined by observing the change of period of a satellite during its whole lifetime. It is customary to take the drag coefficient C_D as 2 in free-molecule flow at high Mach numbers, but this is one of those pleasant simplifications which will no doubt have to be abandoned when we know more about the subject.

The values of density found in this way from satellites are plotted in Fig. 24, and a line has been drawn through them to provide a tentative standard atmosphere between heights of 100 and 200 nautical miles. The pre-satellite A.R.D.C. atmosphere is shown as a broken line, well to the left of the plotted points. The coming of satellites has, it will be seen, resulted in an increase by a factor of between 5 and 10 in the estimated density at these levels.

The drag acting on a satellite in the upper atmosphere can be greatly increased by the effect of charged particles. It is thought that this effect is small for heights up to 200 miles, but there is still scope for argument on this topic and it may be that the density figures will have to be revised.

For most of the satellites so far launched the rate of decrease of period, the factor $\left(-\frac{dT}{dt}\right)$ in the above equation has varied irregularly.[7] It seems most probable that these irregularities are caused by fluctuations in air density near perigee, and satellite orbits offer an excellent means of charting day-to-day variations in density. Of rather more interest than day-to-day variations, however, are longer-term fluctuations, and the rocket of Sputnik 3, for which the period-versus-time curve is given in Fig. 25, showed up these fluctuations strikingly. The observed rate of change of period has been divided by a theoretical rate of change of period (calculated on the assumption that density is constant from day to day) and is plotted in Fig. 26. It will be seen that if the fluctuations are, as is likely, caused by changes in density at perigee, the density at a height of 120 n.m. departs by up to 30 per cent from its mean value. There is also an obvious periodicity in Fig. 26, with peaks at intervals of about 28 days. The period of revolution of the moon, relative to the satellite perigee, is about 22 days, so that it is rather unlikely that the fluctuations are caused by lunar tides. It is more probable that the changes are governed by the sun, which rotates once every 27·3 days, relative to the earth. Streams of particles from the sun sweep across the earth at intervals

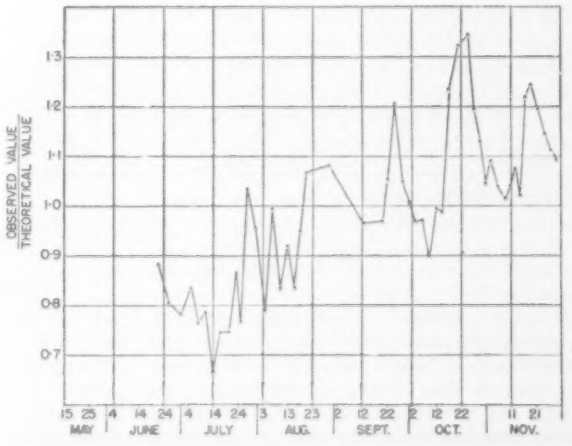


FIGURE 26. Rate of change of period of Sputnik 3 rocket (1958 Section 1) ratio of observed values to theoretical.

of 27 days and give rise to well-known periodicities in cosmic ray activity, geomagnetism and the aurorae, and it is possible that these streams of particles form the mechanism by which the sun governs density. Other effects, such as changes in density from day to night, changes with latitude and with season, also no doubt contribute something to the observed irregularities.

7.3. RADIATION IN THE UPPER ATMOSPHERE

One of the more spectacular results achieved by satellite observation so far has been Van Allen's discovery of bands of intense radiation hundreds of miles above the earth's surface. The first band begins at about 500 miles altitude and has its maximum at altitudes between 1,500 and 3,500 miles, where Geiger tubes have recorded up to 25,000 counts per second. The second band observed by Pioneer 3 has a maximum between 8,000 and 12,000 miles up. The cause of these bands is believed to be the trapping of incoming fast electrons by the earth's magnetic field. The intensity of the radiation is highest on the magnetic equator, although it remains fairly high out to magnetic latitudes of 45° or more. It is believed that the radiation zone is fed by particles from the sun, and that it in turn feeds particles to the auroral zones and is the prime source of the aurora.

The simple concept of a vast region of empty space surrounding our planet has of course long ago been modified, but recent measurements from rockets in the ultra-violet are likely to cause still further, and possibly startling, modifications of our ideas. Thus for example the u.v. luminosity of the night sky in the spectral region of the sun's lyman alpha radiation, which is a characteristic ultra violet wavelength emitted by excited hydrogen atoms, is greater than had been thought. This indicates a greater density of hydrogen in interplanetary space than was previously estimated and suggests that the earth is in fact moving in the outer fringe of the sun's atmosphere or corona. The interest of geophysicists in the sun is thus understandable since, as one American scientist has said, we are actually living in it. The region around the earth known as the exosphere, extending outside the F. layer of the ionosphere, *i.e.* from about 250 miles upwards, is likely to hold increasing interest since it is the region of coupling between the earth's atmosphere and the sun's corona, it is traversed by primary cosmic rays entering the earth's magnetic field, and it is the region of first impact on our atmosphere of streams of particles ejected by the sun, which produce magnetic storms and auroral displays and interrupt radio communications.

8. Conclusions

In this paper the accent has been on the scientific value of satellites, and some of the general design considerations. Little has been said about the guidance systems required for simple orbits, nor for lunar navigation or transfer from one orbit to another. Studies of such problems have been made[8, 9, 10] and much intensive development will be required for the staged orbital stations which may be used for space refuelling on the longer space missions of the future. Doubtless radio relay satellites will be launched and others for meteorological observations; these and future space probes will pose fascinating scientific and technical problems perhaps even more fundamental than those facing the physiologists and biologists in the exciting task of exploring human survival in a space environment. Whether the goal is to launch an instrument payload or a manned space vehicle, the experience and techniques of aeronautical engineering, in all their aspects, will be an essential counterpart to the experimental skill and basic understanding of the physicist.

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DISCUSSION

A. V. Cleaver (Chief Engineer, Rolls-Royce Ltd., *Fellow*): He had listened to the paper as one who often speculated on likely time-scales! He supposed it was safe to confess that, now that astronautics was respectable. They had not yet converted the Astronomer Royal, but at least they had had more success in converting some very patriotic aircraft industrialists now that orders were a little short for conventional aircraft.

He had given a paper six years ago to the British Interplanetary Society, in which he guessed that they might have instrument-carrying satellites by 1965. He was eight years pessimistic there, but in the same paper he also guessed that they might have a manned round trip to the moon by the year 2000, and he thought he would like to modify that and take, perhaps, twenty years off it now. Although he gathered from the paper that the Lecturer did not really

want to be drawn on this, he wondered if he could tempt him to say whether he thought that guess was a very wild one?

Of course, one of the things they had got to do before thinking of these more ambitious achievements was to improve the reliability of their devices. He noted that of the sixteen American satellites and lunar probes that Mr. Stephens mentioned in his paper as having been launched, the successes amounted to four, with two partial successes. They had got to do a lot better than that before putting men in these things.

Turning to the engineering aspects of Mr. Stephens' paper he thought Fig. 15 was extremely interesting. The biggest surprise to him as a rocket man over the past ten to fifteen years had been the extraordinary improvement in the mass ratio obtained—Mr. Stephens' parameter λ or his structural efficiency ξ. Rocket motors, it was true, had got very much larger, but their specific impulse had not improved all that much, and no really high-energy propellant had come into general use. The motor, of course, had itself got much lighter, and this had helped to contribute to this improvement in mass ratio. But with the V.2, they had a mass ratio of about 3½, the Viking after the war was about 5, and only ten years ago he thought most people doubted if there could be much further improvement on this. However, now Mr. Stephens had indicated the possibility of figures approaching 15.

This had been done by very refined structural design techniques, and if there was any more gain to follow in this line, then Fig. 15 might be modified so that the sort of values of ξ that they got now with the denser propellants, might eventually be approached even with such propellants as liquid hydrogen. He wondered whether Mr. Stephens would agree that perhaps this might be so, in which case the argument for developing hydrogen as a fuel would be stronger, of course. From many aspects, it was certainly a lovely fuel to use from the propulsion man's point of view—from the point of view of combustion, for example—and as the Lecturer had pointed out, it was the obvious working fluid for nuclear rockets.

Even if this hope did not materialise and they could not learn how to make these very light tank structures with this propellant of very low density (liquid hydrogen), then, of course, there were other possibilities for the nuclear rocket. They might, for example, use ammonia as the working fluid, because this did dissociate at relatively low temperatures and still produced a working fluid of low effective molecular weight.

He agreed with the implication that the trend in developing satellites might be towards using the higher energy propellants in the smaller upper stages, at least to begin with; in fact, one could already see this trend being followed by the Americans. They were tending to use existing hardware like the Atlas, Titan, Thor and Jupiter vehicles for the bottom stages and develop new smaller upper stages, which might be the first to use these higher energy propellants, such as hydrogen or hydrazine, with oxygen or fluorine.

Mr. Stephens said that the first stage of the Vanguard vehicle was a modified Viking; he would suggest it was a very much modified Viking! He believed it was originally intended to be that, but as in so many such exercises the "mod" got out of hand, and people on the team had told him that about the only thing that was the same now was the outside diameter, as a result of which some of the ground handling equipment could still be used. Anyway, the engine and the propellants were both different. It was worth making the point that, when one made changes like that, one really had got a *very* much modified rocket!

He thought, in fairness to von Braun's Army team at Huntsville, that one should point out the Pioneer III was not (as he thought the paper implied) one of the Thor-Able vehicles. It was a different vehicle altogether from the earlier Pioneers, consisting of an Army Jupiter rocket as the bottom stage, with three solid upper stages consisting of eleven, three and one modified "Sergeants," as on the Explorer satellites.

Mr. Stephens: Regarding the time scale, Mr. Cleaver's guess was as good as his own; his modified time scale gave them twenty years. All he would like to say was that the first thing to solve was recovery. He suggested they would solve that first by recovery of instrumented packages, possibly of complete instrumented payloads, and then they would begin to go forward from the American X.15 work to explore the recovery of human beings. He had simply remarked on what an inefficient package the human body was, and how uneconomic it was to try to transport it in a cabin which also had to sustain re-entry, deceleration and re-entry heating. However, he had no doubt that would all be achieved.

Reliability was a popular word. His only comment was that reliability was the job of the designer; it was not really the job of the scientist who was planning scientific experiments, except as regards the scientific apparatus involved. It was the job of the vehicle designer, and good design led to good reliability. He completely agreed that they dared not trust human beings to space vehicles until the reliability was greatly improved. Regarding liquid hydrogen and its effect on the structural efficiency, or the ease with which one packed fuel, Fig. 15, was, he thought, a not unreasonable estimate of the present state of knowledge; it might well be that, in the future, it would prove possible to improve upon it. The use of ammonia was an alternative but there were toxic risks and so on. He would like to add one remark. The treatment in the paper was deliberately simplified, and tended to infer that they were scared by the total weight at launch—nothing of the sort! People were not scared by enormously heavy aircraft, and they should always be ready to exchange fairly heavy structural engineering, which they knew how to do, for more abstruse problems, such as tackling new propellants, new forms of propulsion, and so on, which might take much longer; he felt that they should not be put off by a launching weight of the order of hundreds of tons. From the remarks about modification he was very gratified to note that Mr. Cleaver was well aware of the danger of undue modification, and he looked forward to seeing the results of this philosophy in the Blue Streak motor.

L. H. Bedford (English Electric Co. Ltd., *Fellow*): He thought Mr. Stephens was right in giving a lot of weight to the section of the paper which dealt with possible scientific dividends. He thought Mr. Stephens sold his case to all scientists present; whether he could sell it to people who had to pay for it was another matter. He was particularly struck in this connection with Fig. 22, which showed that the astronomers, who were the fraternity who had most to gain from this operation, had, up to now, been living with their heads firmly in the sand. Fig. 22 covered a trifling 15 decades of frequency, and showed some very startling information. He could only wish it was more positive and he supposed it could only become so as a result of this sort of experiment.

There was one very interesting feature which leapt to the eye out of that diagram, which was that there appeared to be an absolutely clear window in the atmosphere, which

almost exactly coincided with the range of human vision. He wondered if that was an accident, or if it were true, or if there was some strange correlation there. But it was perfectly clear that if the astronomers could get outside this intensely dense fog, they ought to be able to accumulate a lot of extremely important information. When he said "astronomers," of course he meant the term generally, including such activities as particle physics.

Returning to the question of cost; naturally this operation could never have happened at all if it had not, so to speak, grown out as a sideline from the military operations, and should that background disappear it might be difficult to support the activity. He thought it was difficult to support it, anyhow, and it was quite clear that no industrial organisation could rationally undertake it. It was, therefore, a national undertaking at the least; but what he hoped was that before too long it could be made an *inter*national undertaking, which was the category of treatment which he thought it demanded.

Mr. Stephens: He did not wish to make any detailed comment on cost, although he would observe that it would be unfortunate if the military support were to disappear. As to the cost of the operation however, he would just say this: if one assumed the military support did continue, then he thought that the cost of all the scientific instrumentation and so on should by no means appal them in comparison to monies which were being spent on other scientific work in the country, and he thought that they should take great comfort from the fact that the Royal Society was very actively interested in the possibilities of scientific measurements using earth satellites. This should mean that the problem was put on a proper, national, scientific basis; and it brought in all the talent of the scientists scattered around the Universities and the industrial organisations throughout the country. So he personally felt hopeful that the scientific pressure would prevail. Regarding international co-operation, he thought international co-operation on these types of experiments, certainly on the analysis, understanding and theorising about the results, was feasible and excellent. International co-operation to construct actual hardware was something quite different, and he was sure most of them would agree, was very difficult to achieve at any reasonable tempo—too many people, too many arguments. The important thing was to have one designer when it came to hardware.

H. H. Gardner (Chief Engineer, Military Aircraft, Vickers-Armstrongs (Aircraft) Ltd., *Fellow*): He congratulated Mr. Stephens on achieving what he believed to be a double first. Tonight he had presented the first Main Lecture on Astronautics in the history of the Society, in addition to being the first holder of the newly-established post of Director-General of Ballistic Missiles to do so. It was pleasing also, to note that this lecture coincided with the change in title of the recently formed Guided Flight Section, which was now called the Astronautics and Guided Flight Section. He supported Mr. Cleaver in his remarks that the whole business appeared to be getting respectable.

The paper had revealed many interesting comparisons between the development of earth satellites and manned aircraft. One realised that many of the problems, for instance, propulsion, structural efficiency and payload, were common. Guidance and control, which Mr. Stephens dealt with very briefly for obvious reasons, would reveal other parallels. The whole paper, however, had brought to a head the question of reliability, a characteristic of utmost importance in both missiles and aircraft.

He was interested to hear Mr. Stephens say that man was unreliable and a very poor engineering instrument. As far as reliability was concerned, he was sure the longer they left man out of satellites the more progress they would make towards achieving reliability, as undoubtedly in manned vehicles the pilot had been able to counter and thus cloak much unreliability of equipment.

The payload ratio, *i.e.* the ratio of total weight to payload (values of 350 were not uncommon), indicated the magnitude of the development problem. Mr. Stephens had indicated that this payload ratio might come down as low as 10, which was a measure of the advances, both in structural technique and propulsive efficiency, now being promised. This quest for structural and engineering efficiency would always be a major problem, and, provided propulsion engineers always did a little better than they promised, then he was sure the structural engineers would cope with the problem.

Mr. Stephens, in his final remark, mentioned the Van Allen theory of radiation. He was intrigued to see what was written in the paper and would be glad to have more information on these so-called "deadly" radiation layers which had been discovered by the early satellites and which might limit future manned satellite travel. There was possibly a medical problem there and he would be interested to know what research was being done.

Mr. Bedford raised the all important question of finance. He wished to support very strongly what he had said. One was very impressed with the effort now being expended on so-called "space research." There was an obvious need to pool resources as far as possible, but there was no doubt that the achievement of this ideal would create many difficult international problems. He believed it was essential to limit the expenditure on space research in this country, but he was sure that unless all the work that was being done was carefully studied, particularly from the theoretical point of view, they in this country would be left very far behind. He was impressed and delighted by what Mr. Stephens had told them of the work of the R.A.E. and other Research Establishments, and he hoped in this way it would be possible to keep abreast of all research that was being done in the field of astronautics.

He would like to take this opportunity of paying a tribute to the work of the British Interplanetary Society. A great deal had been done in this country, largely on an amateur basis. A lecture such as they had heard helped one to appreciate and evaluate what had been done by the enthusiasts of this body.

Mr. Stephens: In reply to Mr. Gardner's question about the radiation risks, he thought one could say that, if the manned space mission was travelling to any distant destination the speed would be so great that one might expect the duration of dwell in the radiation belts to be quite small. It would be measured in minutes, and therefore the dosage might very well not reach lethal levels. However, it was very important to qualify that by saying that their knowledge of these radiation belts was embryonic at the moment, and therefore it was not possible to predict whether they would turn out to be harmless or not. He would just remark that there were, of course, many other medical aspects, all associated with the phenomenon of weightlessness. There was one which was amusing: if everything was in a weightless condition in the cabin, the air was also in a weightless condition, and convection could no longer take place because convection depended upon differing densities between hot and cold air. Therefore, if one got into a state of perspiration, one might find it extremely uncomfortable; if one lay down to sleep, then the removal of carbon-dioxide would not be done by the same process of convection as it was in ordinary life, and

there would be quite a problem of ventilation. Of course, since everything was weightless, if they ventilated too hard they simply blew the bodies from one side to the other. So, apart from radiation, there were plenty of problems for the astronautical medical experts.

E. M. Dowlen (English Electric Co. Ltd., *Associate Fellow*): Before the launching of the Sputnik, when the American programme was operating at what one might call a minimum level, one heard quite a lot about attempts to achieve very high velocity with relatively cheap and simple rockets. An interesting example was the " Far Side " vehicle which did, in fact, achieve approximately orbital velocity. Launching was vertically upwards, but it did propel about ten lb. of payload to this velocity with an initial vehicle weight of about 3,000 lb., and presumably quite a low cost.

Now in the field of general research rockets, one had seen, during the period since the war, that the cost of research rockets and their efficiency had increased continuously and he wondered if the Lecturer would like to comment on the possibility, perhaps, of such cheap and simple vehicles which would be capable of lifting small scientific payloads into orbit; whether these things might, in fact, come along in due course with relatively small improvements in solid-fuel motors? Such vehicles might make possible participation in space research for the large number of nations and people in less well-placed financial positions.

Mr. Stephens: Mr. Dowlen had raised a very important and extremely interesting topic. In America there were already several University groups which had been using rockets for atmospheric exploration, and they had managed to produce relatively cheap rockets. In England, there were a number of University groups associated with the Royal Aircraft Establishment who were using the Skylark rocket, which was also moderately inexpensive. The interesting thing was that, by a combination of balloons and rockets, the University of Maryland, the University of Iowa and one or two other groups in America had achieved very significant altitudes with quite useful payloads. This was simply a balance between having to make many firings and many measurements on the one hand, and, on the other, sending up a vastly more expensive satellite which was in the nature of a long-playing record. There would be certain things which it would be much better to do with rockets; it would be a waste of time, money and energy to attempt them in a satellite, and he certainly hoped that sounding rockets would go on. He thought there was every opportunity for some good economical design in solid-propellant rockets—after all there were the French and American experiments, and the Japanese had a whole range of rockets from practically the size of a fountain pen upwards, which they apparently designed themselves and there again, University groups were using these rockets.

The more elaborate experiments which called for long continuous observations outside the earth's atmosphere, or, alternatively, the ability to dip in and out of the ionosphere or the high atmosphere, but dwell for significant periods at great heights, would be the province of the satellite; and there could be little doubt that the satellite would be many orders more expensive than the sounding rockets. However, he fully agreed with Mr. Dowlen that intelligent design of the rocket, and, certainly as important, intelligent, reliable and miniaturised design of the instrumentation and telemetry should pay large dividends.

A. D. Baxter (de Havilland Engine Co. Ltd., *Fellow*): It was very disappointing that, in his summary of the numerous satellite launchings, Mr. Stephens through no fault of his, was not able to mention a single British success, or even a failure. He thought this was something about which they ought to feel rather ashamed and it raised the question of what, if anything, they were going to do about it.

The scientific value of satellites had been shown in the paper and there was a general assumption that this country could reap the benefits of other nations' satellites. It was true that they could make external observations and deductions and, as the poor relation, they ultimately might get some of the internal data from America, but he was convinced that they would learn only a fraction of what could be gained from first-hand experience, and they ought therefore to be doing something much more positive. He believed that they had the possibility to do a great deal by a modest extension of their own programme of rocket work, and if, in fact, they did not enter this astronautical field, they would in the course of the twenty years or so until man-in-space became a fact, decline as an aeronautical and engineering nation until they were second-rate.

Turning to more detailed propulsion aspects, there were two points which were obvious from the range formula (Section 3). These were that improved rocket performance depended upon firstly, improvement in the structural performance represented by the λ value, and secondly, improvement in the thermo-dynamic performance represented by V_E. Considering the former, the paper showed that already the structural weights were so small that one could not foresee great improvements there. In fact, existing rocket engines which only weighed 0·012 lb. per pound of thrust were an order of magnitude lighter than the best turbine engines even at sea level. This emphasised the existing extreme weight refinement and the limitations for future improvement. On the other hand, improvements in V_E need not be so restricted and, in passing, it might be noted that the range formula showed clearly that rocket velocity need not be limited by exhaust velocity. The rocket was the only engine that could travel faster than its own exhaust and this was a much more fundamental reason than that given in the paper why it alone could be used.

Mr. Stephens pointed out that perhaps hydrogen was not quite so good as had been suggested because, for single-stage operation it was not possible to get the mass-ratio necessary for a satellite vehicle. Even accepting this, Fig. 17 showed that using hydrogen with a specific impulse somewhere between 300 and 350 sec. in a two-stage vehicle permitted a very much better stage mass ratio—about 4 : 1 instead of $5\frac{1}{2}$: 1 with an S.I. of 250 secs. This would allow a much higher payload and would in future, be of great importance. Hence, there was a strong case for going ahead with development of high performance propellants even if single stages were not practicable.

On the other hand, looking farther into the future, the nuclear rocket had possibilities of single stage low mass ratios giving all that was required if high exhaust velocity could be provided. Although the reactor might be heavy, quite substantial payloads would be possible. He would say, therefore, that for the future, the three lines that they ought to be developing were, first of all, their own space-rocket, secondly much improved propellants, and thirdly, nuclear rocket motors.

Mr. Stephens: The last sentence of Professor Baxter's remarks was all too familiar—they should in fact be doing everything. It was painfully obvious now that they must be very selective in the things that they could afford to do, and so he would say, purely personally, that it might be necessary to decide which of these developments to put their money on. While, in the very large sizes, he thought

nuclear propulsion might well be promising, in the smaller sizes which might be made possible by miniaturisation of the instruments, he suspected that it might be better to use a combination of staging, which should not really frighten them any more—it had now been done lots of times—and a moderately high S.I. from a chemical rocket. This he thought would give them quite a handsome performance.

M. B. Morgan (Royal Aircraft Establishment, *Fellow*): When they thought of the significance of Sputniks, they tended to think from the Sputnik outwards; they were gripped by the excitement of space exploration—first the moon and then the planets. He would like to emphasise that there was an equally interesting region of endeavour, which should appeal very much to the aeronauts there, and that was from the Sputnik inwards. They were, in fact, steadily increasing the speed of manned flight to several times the speed of sound. Suddenly the speed of unmanned flight had taken a rush of blood to the head, and engineers were now sending devices whizzing round the earth and had already achieved escape velocity. But from the Sputnik they could, he thought, now look inwards, and vigorously attack the problem of going faster and faster for earthly purposes; for travelling from *A* to *B* on this world. The earth was still quite a big place, and in the future, looking ahead some decades, there might well be great virtues in going extremely swiftly halfway round the world—about 12,000 miles—carrying passengers and freight. For purposes of that sort, it might well be that the lessons they learnt now in going at the great speeds and heights necessary for Sputniks and astronautics would be extremely useful.

He would like to draw the Lecturer a bit on manned re-entry. There was no doubt at all that heroic efforts would be made from various parts of the world to get men into orbit; and undoubtedly, men being men, heroic efforts would be made to get them back again. He would welcome the Lecturer's views on how they were going to get back. Where they going to return in a big sphere or ball which threw out various braking devices and finally came down with an inelegant "plop" in the sea? Or were they going to come down in a civilised way in a nice-looking aeroplane with the pilot sitting with a stick between his knees, eventually driving the thing back to earth in the good old-fashioned way? He had a vested interest in this in a way because he rather liked these nice long, slender, controllable shapes; aerodynamically they were so much more interesting than spheres.

Mr. Stephens: He was glad that the spirit of conventional aviation was not yet dead! He would have thought that those remarkable shapes which he had shown on the slides could be even more intriguing aerodynamically than the long, slender Deltas, or the spheres; they were certainly a great deal more difficult.

Regarding manned re-entry, he thought that this would have to be achieved by a skilful combination of drag and lift; in theory one could re-enter using drag alone, and arrive on the ground intact, provided the structure, the interior equipment and the inmates could stand very high deceleration. All the calculations which had been done on re-entry of rockets went to show that this should be a good proposition and President Eisenhower had displayed on television a cone which had successfully re-entered the atmosphere; so the re-entry problem had been solved for a certain type of structure. Once they subjected the frail human body to this type of re-entry, they were immediately deprived of the benefit of the high deceleration at high altitude, and the body was also very fussy about the temperature environment. Therefore the solution for manned re-entry would probably be to develop a small amount of lift in order to prolong the re-entry path and so spread both deceleration and heating over a much longer time. With a careful combination of lift and drag in the fringe of the atmosphere, and suitable heat insulation, theory suggested that re-entry without excessive deceleration should be feasible. There had been one or two very interesting N.A.C.A. reports on this problem, notably by Chapman and Julian Allen. However, as so often happened, stability and control might prove to be the critical factors because the calculations showed that the perturbation to a re-entry path due to a very minor mistake in steering the vehicle was such that the occupants could either be decelerated into a pulp or burnt to a crisp. He might say in response to one of Mr. Morgan's remarks that the pilot was likely to come back with, not a stick, but his head between his knees.

Captain the Hon. G. B. Bathurst (Journalist, *Companion*) (*Contributed*): He had to admire the paper for its lucid quality, even to a layman, but confessed to wondering if it was not also designed to convey an implied proof that space flight on anything but a mechanical scale was unobtainable for all but the largest nations—or groups of nations, if they were ready to group. He was reminded of a similar decision by the Ministry of Supply with regard to supersonic flight and he very much doubted they had not had cause to regret that decision after it was made.

Without blaming the lecturer for not exhibiting second sight he would like to ask Mr. Stephens if an estimate had been made in respect of a manned satellite programme, and if so, if it was tied to a rocket configuration as in Fig. 16?

Secondly, assuming the cost of the first stage was the major part, one wondered what difference it would make if, in flight, refuelling became possible, and how many refills would be necessary in respect of the second stage to dispense with the first?

In the course of the lecture, mention was made of the problems involved of a navigational nature for in-space refuelling rendezvous. He would like to ask if anyone had thought of using extended aircraft of the North American X.15 type as tankers, one or more being enabled to enter a permanent orbit reaching satellite height in the process, by being re-fuelled on the probe and drogue system outside the atmosphere? In that case the pilot might be worth his weight in electronic gadgets without the need to work out rendezvous navigation as accurately as all that.

Mr. Stephens: He had not made any cost estimates for a manned satellite programme, nor had he seen any proposals to use vehicles similar to the X.15 to provide refuelling tanks. The difficulties of making an exact rendezvous in orbit were likely to be such that only a complex computer would be able to solve the navigation problem; he did not believe that the pilot would be capable of doing more than monitor the functioning of the navigation instruments.

Sir Arnold Hall in closing the meeting congratulated the Lecturer on his excellent paper and on the entertaining way in which it had been presented.

TECHNICAL NOTES

Notes on Guidance and Control are particularly invited.

Wakes in Axial Compressors

by

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THE tendency in the past has been to assume that when wakes or non-uniform total head profiles are fed into an axial compressor then substantially constant static pressure prevails at the entry, the variations in total head appearing as variations in velocity. This variation in velocity causes variation in incidence on the early stage blade rows and thus can give rise to excitation of blade vibration. This assumption is implicit, for instance, in References 1 and 2, but we think has been a common assumption by most of the people working in this field.

Where the compressor is fed by a duct of substantially parallel walls for a reasonable length ahead, such an assumption appeared justifiable. Such a duct when given an air flow test with its outlet discharging, for instance, to atmosphere instead of to the compressor, then the distribution assumed would normally be obtained and in fact many surveys of such ducts have been represented in this fashion. The object of this note is to show that, in fact, this distribution will not normally occur when the compressor is present and we may normally expect much more nearly a constant velocity into the compressor with attendant static pressure distributions to match with the total head variations ahead of the intake, with of course, the attendant curved flow to support the static pressure gradients.

It can be shown on two separate simple arguments that in fact the flow into the compressor must be *approximately* (but in fact not quite) at constant velocity. Suppose, for instance, the intake flow was made up of two equal parts at different total pressures and we regarded the compressor as made up of two separate compressors in parallel, one taking in the air at high and the other at low total pressure. Assuming the compression ratio to be reasonably high, the characteristic would be of substantially constant inlet $M\sqrt{T}/P$, *i.e.* $V/\sqrt{T}$, and therefore, since uniformity of temperature is assumed, the velocities into both compressors would be the same. In order that the pressures should match at outlet, the lower inlet pressure compressor would be operating further up its characteristic and thus at slightly lower axial velocity.

In fact the two compressors in parallel would not be independent and to make the analogy more exact it would at least be necessary to alter the area ratio of the compressors, *i.e.* assume that one compressor would occupy more than half the area of the back end. In this way one of the compressors would in fact function at rather more reduced flow than the other. The main point, however, is that the two velocities would be much nearer constant velocity than constant static pressure.

The second argument which follows is more strict. Consider the main flow as operating at design speed and axial velocity and a wake to consist of a low total pressure region. First suppose that the flows are at constant static pressure, then the wake will be at low axial velocity. Consideration of the velocity triangles of a conventional first compressor stage will show that provided the wake is not strong enough to stall the blade rows, then the static pressure rise in the wake flow will actually be higher than in the main flow. Thus at outlet from the first stage the static pressure will be higher in the wake than in the surrounding flow, though the total pressure may still be lower. Thus no sensible equalisation of the wake as it flows through the compressor is possible along these lines.

Secondly, assume that the flows are at constant velocity and different static pressure. Then the total and static pressure ratios in both main stream and wake are exactly the same and the wake will persist right through the compressor. In fact, tests will show that the wake slowly disappears, thus it is clear that the velocities must be nearly uniform and in the wake slightly less than in the main flow.

After the first stage both total and static pressures will be slightly more even than previously. Thus there will still be curvature of flow to preserve the static pressure gradients.

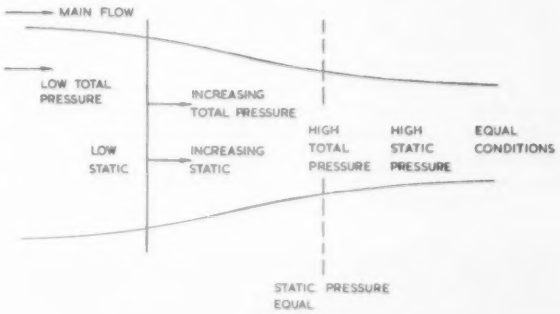

FIGURE 1.

The sequence would be expected to be as shown in Fig. 1. Ahead of the compressor there is a region of constant static pressure, and low total pressure in the wake. At the compressor face the static pressure in the wake is low with nearly normal axial velocity and curvature of the stream lines. Through the early stages both static and total pressures are increasing in the wake compared with the main stream. Eventually a point is reached at which the static pressure in the wake is equal to the main stream, there is no curvature and the total pressure will be somewhat higher than the main stream. To bend the streamlines back to the straight direction again the static pressure in the wake will actually have to rise above the

Received 8th June 1959.

mainstream slightly until eventually even conditions exist presumably quite a long way downstream.

These arguments do not involve any question of mixing, though this must occur at the edges of the wake and will undoubtedly complicate the situation Although the streamlines are curved, this merely occurs as a variation in incidence across the wake and mainstream.

For wakes of reasonably small angular extent the foregoing should represent the general picture if the number of blades were very large. For finite blade numbers mixing within blade passages must represent a large contribution to the general picture.

For wakes of large angular extent probably finite blade numbers are not of great importance, but the picture shown is not correct because it is not necessary to support static pressure gradients by curvature of the streamlines alone, since the curved sides of the annulus walls themselves will support some or all of the pressure. However, this does not change the general fact that wakes will appear largely as variations in static pressure.

The effect of this distribution is important because it changes the nature of the blade vibration phenomenon completely. It is now to be realised that the main effect of a wake will be to cause a variation in static pressure round the annulus at roughly constant incidence conditions.

The lift force on the blade will be proportional to density or very nearly to the static pressure in the annulus. Little error will be involved in assuming that this is proportional to P, the total pressure, there. The damping force on the blade will also be proportional to this same total pressure, so the basic equation governing the vibration will be:—

$$L\frac{d^2y}{dt^2}+kP\frac{dy}{dt}+Ty=cP,$$

where k and c are constants and L and T are inertance and stiffness of the blade respectively.

If P is a simple sine function, for instance, we have:—

$$L\frac{d^2y}{dt^2}+k\,(P_0+\Delta P\sin pt)\frac{dy}{dt}+Ty=c\Delta P\sin pt$$

and the equation is by no means a normal second order differential equation.

If the wake appeared as a straight variation in velocity at constant static pressure this would give:

$$L\frac{d^2y}{dt^2}+kP_0\frac{dy}{dt}+Ty=c\Delta P\sin pt.$$

This is a normal second order differential equation and leads to straightforward resonance in which the peak amplitude is independent of inlet pressure for constant $\Delta P/P_0$.

For wake excitation according to this new view, if the air amplitude variations of total pressure are small, the vibration equation may be written as:—

$$L\frac{d^2y}{dt^2}+kP_0\frac{dy}{dt}+Ty=c\Delta P\sin pt,$$

so that it will be seen for small excitation the two views give much the same result. For large amplitudes of excitation on the new view the excitations will affect the damping term as well as the excitation term and the equation is no longer of second order with constant coefficients.

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1. Pearson H. (1953). The Aerodynamics of Compressor Blade Vibration. Fourth Anglo-American Aeronautical Conference, The Royal Aeronautical Society, 1953.
2. Parry, J. F. W. and Pearson, H. (1954). Cascade Blade Flutter and Wake Excitation. *Journal of the Royal Aeronautical Society*, Vol. 58, Number 523, p. 505, July 1954.

Safe Mechanisms

COMMENT BY A. H. CRAWSHAW, A.F.R.Ae.S.

(Blackburn Aircraft Ltd.)

I SHOULD like to thank Mr. Hafner for his paper on "Safe Mechanisms" published in the May Journal (p. 273). There is much scope for thought and invention along the lines he suggests and such thought will result in increased safety.

In Section 3.1 on page 276 "Safety Standard," it is suggested that accident statistics should be quoted on an hourly basis and not per mile. A man expects to live three score years and ten; it is, therefore, the risk of spending a proportion of this time in a given occupation which is significant. It is then possible to compare the relative risks of lying in bed, train travel, air travel, space travel and so on. The risk of lying in bed cannot be assessed on a mileage basis and space travel would appear far too safe on such a basis!

The figures in Mr. Hafner's paper are plotted against time as a base and not miles.

Received 27th May 1959.

MR. HAFNER'S REPLY

The criterion by which one compares the safety standards of different environments (whether bed or space ship) must reflect a function (sleeping or travelling) which forms a common denominator of all the environments.

The common denominator to beds and space ships is that one can sleep in both, and the safety criterion must then be on an hourly basis. But if your object is to travel you must select environments that move and then judge them on a mileage basis.

One can visualise an airline with a magnificent safety record of twenty years without an accident. On closer examination, however, it may become apparent that the entire organisation had spent these twenty years in bed!

Emergency Passenger Oxygen Systems

by

Squadron Leader N. CROWE, A.R.Ae.S.
(The Walter Kidde Co. Ltd.)

WITH modern air liners flying at altitudes of 20,000 ft. or more, the question of passenger safety in the event of pressure cabin failure has become a real problem. Should failure occur, the Captain of an air liner flying over the sea, or difficult country, would have to decide between exposing his passengers to the anoxic effects of high altitude or of accepting the increased fuel consumption which would result from flight at a lower altitude.

An Emergency Passenger Oxygen System to enable the flight to continue at an altitude where fuel consumption would not be excessive has been developed recently by the Walter Kidde Co. Ltd. in conjunction with the Scott Aviation Corporation of America. The Mask Presentation Units included with this system are unobtrusively located in the luggage rack and, in the event of pressure cabin failure, an oxygen mask is automatically presented in front of the head of each passenger. It is then only necessary for the passenger to pull the mask on to his face to obtain a supply of oxygen at sufficient flow to safeguard him until the aircraft has been brought down to a lower altitude. In addition, each Presentation Unit includes an attachment point for medicinal or therapeutic oxygen, which is independent of the emergency system, and from which a supply is always available. Leakage from these points when not in use is prevented by self-sealing outlets. The Presentation Units are easily removable for overhaul purposes and can be adjusted for a change of seat layout. A manually operated cock enables a crew member to operate the system if necessary. Fig. 1 illustrates the system in use.

The weight of the equipment is approximately 2 lb. per passenger; it is already in service with one airline in the U.S.A. and is also being used on some Comet 4's of B.O.A.C.

DESCRIPTION OF SYSTEM

A schematic diagram of the system is shown in Fig. 2. Two sets of cylinders feed into a low pressure ring main which is located in the aircraft cabin. The Mask Presentation Units are connected to the ring main by quick acting couplings, each of which includes a self-sealing outlet. Of the two sets of cylinders, one supplies "High Flow" oxygen during an emergency period, while the other supplies "Low Flow" oxygen during the post-emergency period, in addition to the therapeutic outlets. One 1,400 litre cylinder is usually enough for the emergency period, while two or more of the same, or larger, capacity will be required for both the post-emergency period and the therapeutic outlets. The available capacity will depend on the passenger load and stage length.

In the supply line from the "Low Flow" cylinders is a Therapeutic Manual Control Valve located near a member of the crew. With the valve in the "on" position, oxygen will flow into the ring main through a reducing valve set to control the ring main pressure at a nominal of 40 p.s.i. While this pressure remains at approximately 40 p.s.i. the Mask Presentation Units will not open. In this condition oxygen is always available at the self-sealing therapeutic outlets, and it is only necessary to connect the bayonet fitting on the mask tube to obtain a supply of oxygen at a pre-set rate.

Received 30th April 1959.

Immediately upstream of the manually-controlled valve is a pressure gauge which registers cylinder pressure at all times. This gauge incorporates a warning mark, below which pressure must not be allowed to drop. In this way, oxygen at sufficient pressure is maintained in the cylinders to provide for a post-emergency period.

The "High Flow" supply line includes an automatic turn-on valve with over-riding manual control (*See* Fig. 3). This valve is normally closed, but is opened at approximately 14,000 ft. cabin altitude, under the action of an aneroid. Oxygen is permitted to flow from the High Flow cylinder through a reducing valve set to control the pressure at a nominal of 80 p.s.i., the Mask Presentation Unit doors will drop open, and the mask is presented just above, and in front of, each passenger. The passenger then draws the mask down to his face to obtain a supply of oxygen. This action opens a stop valve which is included in the flexible mask tube, while a small spinner indicates that oxygen is flowing. By this method a wastage of oxygen is prevented, since a flow will not be induced until the mask is pulled down and the stop valve removed from its retaining clip.

During the time taken to exhaust the High Flow cylinder, approximately eight minutes with full passenger load, oxygen cannot flow into the Low Flow system, but once this cylinder empties, and the ring main pressure drops to approximately 40 p.s.i. the Low Flow system will come back into operation. The passengers still requiring oxygen will thereafter be supplied from this source.

When the immediate emergency is over the oxygen supply from each Mask Presentation Unit can be stopped by means of a press button mounted near the therapeutic outlet. The control valve operated by this button will not remain closed if a pressure greater than approximately 50 p.s.i. remains in the ring main, thus ensuring that the unit cannot be isolated while the emergency lasts. If any passenger still needs oxygen the press button control valve is left open, and the remaining positions in the same Presentation Unit can be isolated by returning the stop valves to their stowed position in the unit. The therapeutic connection remains independent of this control valve.

FIGURE 1.

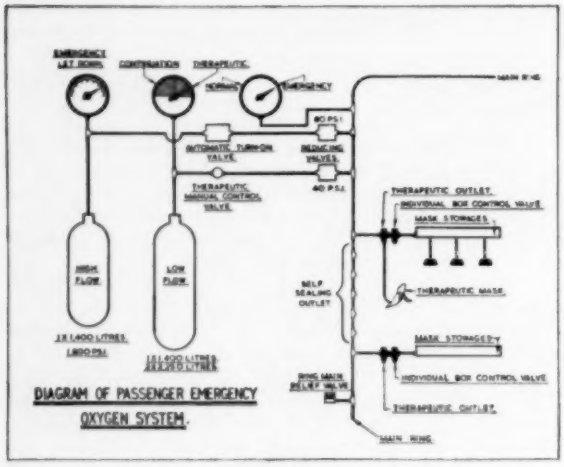


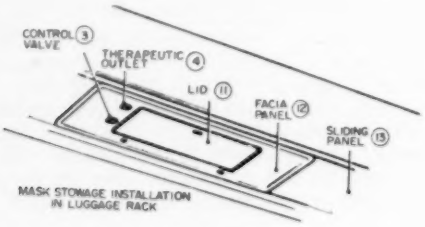
FIGURE 2.

A relief valve connected into the ring main prevents inadvertent operation of the system due to any leakage past the High or Low pressure reducing valve. It does not, however, affect the operation of the system in an emergency, and the leak rate past the relief valve is negligible while the emergency lasts.

Suitably calibrated pressure gauges are used to indicate both high and low flow cylinder contents, as well as ring main pressure.

THE MASK PRESENTATION UNIT

Each of the Presentation Units includes either two or three masks as required. Flexible hoses which contain a stop valve and a visual flow indicator in their length, connect the masks to the unit at an orifice block which incorporates a press button control valve and a therapeutic outlet. A flexible coupling connects the orifice block to the ring main by means of a bayonet socket.



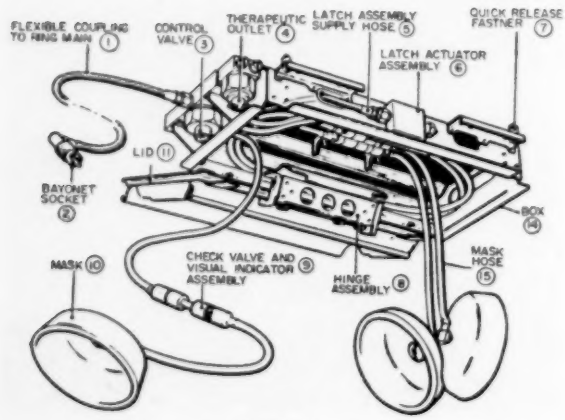


FIGURE 4.

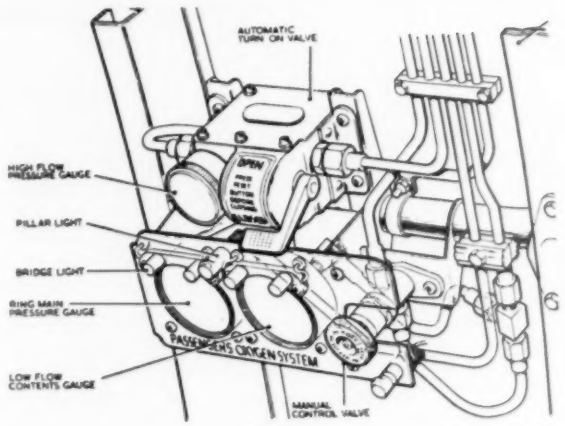


FIGURE 3.

Figure 4 shows the Unit in its installed position with the lid closed. It is also shown with the lid open after the pressure sensitive latch has been sprung.

ACTION—LOW FLOW

With the therapeutic manual control valve open, oxygen at approximately 40 p.s.i. flows from the ring main to the therapeutic outlet. This outlet is of the self-sealing type, so that leakage is prevented until a therapeutic mask is connected. Oxygen is then available at the rate of a nominal 2·5 litres per minute at ground level, although this can easily be adjusted by means of an adjusting screw located in the outlet.

ACTION—HIGH FLOW

When the aneroid operated turn-on valve opens with decreasing cabin pressure, oxygen at a nominal 80 p.s.i. flows from the ring main to the control valve in the orifice block of each Presentation Unit. This control valve will open at a nominal pressure of 65 p.s.i., and will permit oxygen to flow along a transverse port to each of four orifices designed to control the flow at a nominal of 3·4 litres per minute at ground level. One orifice leads to the pressure sensitive latch assembly, and the other three to the masks. The latch assembly is mounted on the front face of the Presentation Unit and consists of a plunger which is operated by the movement of a diaphragm. Increasing pressure upstream of the diaphragm moves diaphragm and plunger forward, releases the latch, and permits the lid to drop open, assisted by two coil springs. The lid opens through 180° to ensure that the masks have an unrestricted drop in front of each passenger. The stop valves in the flexible mask connections are normally stowed in the closed position against an internal spring in compression. The action of pulling the mask on to the face releases the stop valve from its retaining clip and the valve opens. A visual flow indicator in the form of a small red spinner indicates that oxygen is flowing. The mask is simple and is manufactured from soft sponge rubber to mould effectively to any type of face. No straps are used to support the face-piece, since it is light enough to be hand held.

Wastage of oxygen through the face-piece is negligible. The press button control valve will automatically close when the system pressure falls to approximately 28 p.s.i. but can be closed manually after the pressure has fallen below a nominal 50 p.s.i.

THE AUTOMATIC TURN-ON VALVE

This valve is illustrated in detail by Fig. 5 and its object is to provide for an automatic release of oxygen into the ring main in the event of cabin pressure failure. The valve is enclosed in a body, the interior of which is open to cabin pressure. Oxygen enters the valve through an inlet port, and is stopped by a needle valve which is closed. The needle stem is connected to a damper through a trunnion assembly, an operating link and a cocking lever. The damper is spring-loaded to retain the needle in the open position, but is restrained by a sear lever which engages on a sear plate attached to the cocking lever. The other end of the sear lever is in contact with an over centre leaf spring which is attached to an aneroid. A pressure gauge which registers high flow pressure, a hand lever, and reset button are mounted externally on the body (*See* Fig. 3).

OPERATION—CLOSED POSITION

Oxygen at approximately 1,800 p.s.i. enters the inlet port, but a flow is prevented by the closed needle valve which is held on to its seat by the cocking lever and the sear plate in contact with the sear lever.

AUTOMATIC OPERATION

In the event of cabin pressure failure, the aneroid will tend to expand against the opposing load of the cocked leaf spring. Energy is stored until, at approximately 14,000 ft. cabin altitude, the expansive force of the aneroid is sufficient to push the leaf spring over centre. The sear lever is removed from the sear plate, and the damper assembly is permitted to expand under spring pressure. The cocking lever pivots and the needle opens under the influence of the operating link and trunnion assembly. Oxygen will then flow through the needle valve to the outlet port, and so to the ring main. The damper assembly will ensure that the valve opens slowly allowing the pressure to build up in the system without any measurable rise in temperature.

MANUAL OPERATION

When the hand lever is moved to the "Open" position an integral cam moves against the sear lever and removes it from the sear plate. Thus the automatic action is by-passed, and the needle opens.

RESETTING

The turn-on valve can only be reset manually, but this action cannot take place until the aneroid has contracted sufficiently to permit full movement of the leaf spring. When the reset button is pressed in, the leaf spring returns

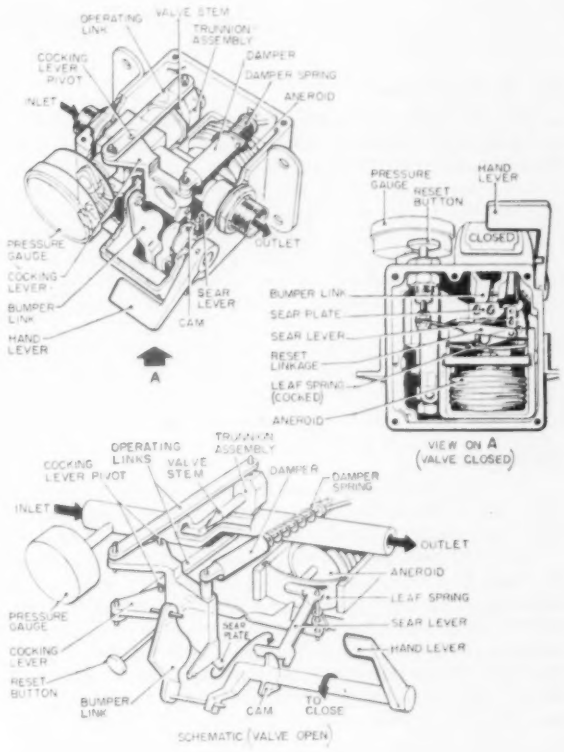


FIGURE 5.

to the cocked position. The hand lever is moved to "Closed," the cocking lever is pivoted by the bumper link and the needle valve is closed. The sear lever moves into position on the sear plate, and the needle is retained in the closed position. This action also compresses the damper spring and the unit is reset for automatic operation.

CONCLUSIONS

With this system fitted to high altitude passenger aircraft every precaution has been taken to ensure the safety of passengers in the event of a decrease in cabin pressure. The high flow system has sufficient duration to safeguard the passengers during the immediate emergency period, and the flight can be continued where reasonable fuel consumption can be expected. The low flow system is always available for use if required, while unused positions can be isolated by a crew member to prevent wastage if the emergency system has been used.

The author wishes to thank the Directors of the Company for permission to publish this note, and his colleagues at the firm for their assistance in its preparation.

Graduates' and Students' Section

New Representatives

The following additional people have offered to act as local representatives, and should be contacted for details of meetings, tickets, and so on.

Name	*Company*	*Address*
J. D. Brown	Fairey Aviation Ltd., Hayes	1 Crowlands Avenue, Hayes, Middlesex
Fg. Off. M. Minden	R.A.F. Bassingbourn	Officers Mess, R.A.F. Bassingbourn, Royston, Herts.
A. Le Ray-Cook	Vickers-Armstrongs (Aircraft) Ltd., Weybridge	90 Edenfield Gardens, Worcester Park, Surrey

Summer Party

The now traditional Summer Party was held on Friday 12th June at Hamilton Place. Once again we were blessed with ideal weather, despite rain earlier in the day.

Over 150 members and their guests danced to the music of Hugh McCamley, enjoyed food provided by the long suffering wives and girl friends of the Committee, and polished off the liquid refreshment.

The photographs are two of a selection taken during the evening, and others may be seen at the Society's office. Copies are obtainable from the Honorary Secretary of the Section.

Letter to the Honorary Editor

The following letter has been received. We would welcome comments on its contents as it raises a question which is of great importance to Graduates and Students.

9th June 1959

Sir,

It is often the complaint of Graduates and Students that membership of this Society has little or no professional status. In consequence many people place more value on membership of other Institutes, and sometimes even consider membership of the Royal Aeronautical Society not worth the subscription.

One reason for this belief is surely the apparent unwillingness of aircraft firms, Government Departments and the Aeronautical Society itself, to make Associate Fellowship a compulsory or even a desirable condition of employment when advertising for staff. The Appointments section in recent issues of this JOURNAL have contained only one advertisement which specifically mentioned membership of the Society. It could be argued that; as the JOURNAL is intended primarily for members, reference to Society qualifications is superfluous, but the fact remains that it is read by many who are not members and who should be encouraged to join. In the National Press, reference to Associate Fellowship is extremely rare; in fact the Royal Aeronautical Society may just as well not exist for many in the Aircraft Industry.

In other branches of industry and Civil Service, membership of a relevant professional body is often a condition of employment and in many cases brings additional financial reward. Before full recognition is obtained for Royal Aeronautical Society membership, it must be demonstrated that it is accepted by the Aircraft Industry itself as being a valuable qualification. One obvious way of doing this is by making such qualifications a condition of employment. Until this is done one can hardly expect the situation to change.

As most aircraft firms are represented on the Council of the Society it would seem to be a relatively simple matter to obtain the Industry's support in a possible attempt to promote the Society's well-being and perhaps reduce some of the apathy among its younger members.

Yours etc.,

JOHN F. WILBY.

350 London Road,
St. Albans,
Herts.

The Summer Party—in the Library and right, on the terrace. Photographs by D. PRESTON.

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Reviews

POLAR ATMOSPHERE SYMPOSIUM. *Pergamon Press. Part I. Meteorology Section. 350 pp. 70s. Part II, Ionosphere Section. 212 pp. 60s.*

The Symposium concerned in these publications was one held under the auspices of AGARD. It arose from a Norwegian suggestion and was held in Oslo on 2nd to 8th July 1956. This was a fortunate choice because it supplies a good background on which to build with the help of the new knowledge acquired during the International Geophysical Year of 1957-8.

The polar atmosphere is now a subject of great military and civil interest from both the meteorological and ionospheric aspects. At the same time it presents scientific problems of great interest and complexity.

In his introductory address Dr. Sverdrup called attention to an essential meteorological difference between the polar and tropical atmospheres. Whereas the most important energy transformations in the tropics are due to the addition of latent heat to the atmosphere by condensation of water vapour, in the polar regions this is unimportant compared with radiative processes. This provides a justification for a conference devoted primarily to the polar atmosphere, at least on the meteorological side. From the point of view of the ionosphere and radiocommunications there is even less difficulty in singling out high latitudes for special consideration—all phenomena which depend in some way or other on the bombardment of the atmosphere by charged particles from the sun or elsewhere depend strongly on latitude and usually exhibit most potent effects near the poles.

The meteorological proceedings are described in four sections. The first is concerned with polar geography and climate. One paper of special interest was that by R. M. Holcombe who discussed the similarities and contrasts between the Arctic and Antarctic Marine Climates. In general terms Antarctica is a land mass surrounded by water whereas the Arctic is a water mass surrounded by land and this leads to many big differences of climate. In the same section Th. Hesselberg and T. W. Johannessen described work on the variation of temperature and other climatic conditions at Norwegian Arctic stations since 1912. No marked changes were observed until 1917. A rapid rise of temperature then occurred until 1922 and continued more slowly until the war. Since then the temperatures are somewhat lower. The importance of the much more extensive sets of observations planned for the I.G.Y. was emphasised.

The second section dealt with winds and temperatures, the third with weather and weather prediction, and the fourth with radiation, ozone and the distribution of ice. Among the many interesting subjects discussed was the Arctic "whiteout".

On reading the proceedings one is struck by the vast amount of data which must be handled in all meteorological investigations. Thus in 1953, 25 million punched cards of marine meteorological observations were stored in the National Weather Records Centre at Asheville, N.C. in the U.S.A. The amount gathered during the I.G.Y. must have increased this wealth of data enormously—and yet there still remains much more to be learnt about the polar regions. On the whole, however, the meteorological proceedings make interesting as well as instructive reading and the discussion after each session is well reported and lively.

The Ionospheric Symposium was broken up into three sections. Section I includes a number of papers on the measurement of ionospheric drifts and irregularities. This is of special importance for the polar ionosphere which is considerably more uneven and sporadic than at lower latitudes. Of particular interest in this section is a theoretical paper by H. G. Booker on Turbulence in the Ionosphere with Applications to Meteor Trails, Radio Star Scintillation, Auroral Radar Echoes, and Other Phenomena. This attempts to apply the statistical theory of turbulence to the high atmosphere and thence to relate a wide variety of observed phenomena. There is no doubt that this is a very important contribution from all points of view. Application is even made to the assessment of the practicability of radio communication through incoherent scattering by irregularities in the F-region of the ionosphere. Although there will certainly be many modifications eventually introduced in Booker's theory, it nevertheless contains a number of ideas of basic importance.

Section II was concerned mainly with prediction of ionospheric conditions in the Arctic. This is complicated by the irregular occurrence of polar blackouts. These phenomena depend on solar conditions and prediction must be based on the establishment of correlations with the solar effects. This is a very big subject, still in an early state, so that it is not surprising that forecasting of ionospheric "weather" at polar latitudes is a very difficult art. Here again data obtained through the intensive observations made during the I.G.Y., a period of strongly disturbed solar conditions, will undoubtedly help considerably—provided, again, the large amount of data obtained can be adequately analysed.

The final section includes two theoretical papers, one an application by Booker and Cohen of the former's theory of turbulence to the interpretation of the long duration of radar echoes obtained from meteor trails.

As with the meteorology symposium, the discussion was lively and informative, and it is very useful to have the material published at this stage. In both volumes the format is pleasing and the numerous diagrams clear. They are likely to prove of value for reference purposes for some time to come.—H. S. W. MASSEY.

AXIAL FLOW COMPRESSORS. *J. H. Horlock. Butterworths, London, 1958. 189 pp. Illustrated. 40s.*

This is the first book written in English to deal solely with the axial flow compressor. The field on the subject is comprehensively covered from the fluid mechanic and thermodynamic viewpoints. Training to graduate level is assumed, but it is a readable effort and makes a useful reference work for all concerned with these turbo-machinery components. More specialist workers will find plenty of food for thought in it, and throughout the book the author makes many useful comments on difficult aspects.

Page 2 of the first chapter, on fundamental knowledge, starts off with vector methods, but this should not frighten off those unfamiliar with such methods, as they are not much used afterwards. The section on p. 3 introducing Bernoulli's equation starts "Since the scalar product of $\bar{c}$ or $\bar{\omega}$ . . ." The reviewer prefers a less advanced approach! Chapters 2 to 7, dealing respectively with theoretical cascades, experimental cascades, two-dimensional stage

design, three-dimensional flow, characteristic calculations, and stalled performance are first rate and really attempt to make full use of the published information. The last two chapters, 8 and 9, on compressor design and supersonic compressors, are very limited in scope. An attempt is made in an appendix to give a preliminary design study of an axial flow compressor. There appears to be little correlated data available on high speed cascades and on the subject of secondary pressure losses, though successful compressors continue to be designed without this information. A much better understanding is still required of stalled and surged conditions.

In general the presentation is good and the diagrams are clear. The nominal 189 pages are matched by the same number of references, and lists of symbols are given at the end of each chapter. The system chosen for angles is not ideal, for example with cascades in Chapters 2 and 3 the air angle at exit is α_2, while for Chapter 4 in a stage the same symbol becomes the air angle at entry to the stator blade. The references include most of the important contributions made in the world outside Russia, though the majority are of British or U.S.A. origin. The actual text, perhaps rather naturally, depends to a large extent on the British contributions by Carter, Hawthorne, Howell, the author himself and others. During the last twenty years or so research and development work on axial compressors has been pursued steadily with successful results. Reading this book still emphasises the "hit and miss" nature of design and so the need for better correlation of the existing data and a greater rationalisation of principles and methods. For the practical designer, a few parts of the book are difficult and many questions are left unanswered. The research worker will find it an excellent source of ideas and data. It is a good attempt to present the basic information.—A. R. HOWELL.

THE BOMBER'S EYE. *Dudley Saward. Cassell, London, 1959. 264 pp. Illustrated. 21s.*

A number of books giving accounts of the evolution of radar in this country have already been published; notably A. P. Rowe's *One Story of Radar* and Watson-Watt's *Three Steps to Victory*. An account of the operational use of radar in Bomber Command has also been given by D. C. T. Bennett in his book *Pathfinder*. The book by Dudley Saward is supplementary to these, for it gives the story as seen from a very valuable vantage point, in that the author was neither a "boffin" nor an "operational type" but one of those excellent people who gave effective help in welding the two species together.

The early part of the book gives an account of the work of the Blind Approach Technical and Development Unit at Boscombe Down in investigating and assessing the German blind bombing methods, and of the author's own part in getting agreement to make active attacks by bombing on the ground stations involved rather than relying entirely on counter measures. Although the Boscombe unit was widely known as "Lywood's Private Air Force" it is perhaps due to the sands of time that no mention at all is made of the late Air Vice-Marshal in the book. Then follows a thumb-nail sketch of radar activities in Fighter Command covering the Battle of Britain era, but the main substance of the book is an easily read account of the introduction of the various radar bombing devices, Gee, H_2S, Oboe, and G-H, into Bomber Command, with interesting anecdotes of the many personalities involved both at the Telecommunications Research Establishment and in the Royal Air Force. The reasoning behind many of the policy decisions, especially with regard to H_2S, makes interesting reading, and the notable part the author played in a "behind the scenes role" in H_2S is brought out for the first time.

In a way it is a pity that Group Captain Saward did not find it possible to publish the account of his war-time experiences until some fourteen years after the end of hostilities, in that a number of details are now obviously somewhat hazy, if not incorrect, although these do not detract greatly from the general interest one finds in reading the book. For example; on page 20 in describing a dot-dash radio beam Saward writes "the closer the aircraft approaches the equi-signal zone the shorter is the gap and the quicker the dots follow on each other . . ." In fact, of course, the dots are equally spaced in time and it is the amplitude or volume ratio of the dots and dashes which enable the pilot to locate the equi-signal area at the centre of the beam. And did the initials R.D.F. (on page 4) really mean "reflection detection finding"?

The book is well illustrated and free from printing errors. It is suspected, however, that on page 34 Professor Blackett would prefer to see his name spelt with two "t"s instead of the printed "Blacket"; while on the same page there is no doubt that Sir Henry Tizard would prefer to see his name without the double "z" in the printed "Tizzard". The book is certainly to be commended to anyone who is interested in learning the part that radar played in bomber operations, and will also be of interest to those who themselves played a part in these activities but who would like recalled some of the high-lights of the war-time days.—F. E. JONES.

ADVANCED MECHANICS OF FLUIDS. *Hunter Rouse (Editor). Chapman and Hall, London, 1959. 444 pp. Illustrated. 78s.*

The editor of this book is the Director of the Iowa Institute of Hydraulic Research and the work of writing the book has been shared between a number of authors on the staff of that Institute. It is clear that the editorial work has been well done, and in view of the number of authors involved the uniformity of approach and style is remarkably good.

The book is intended as a textbook for an advanced course in fluid mechanics, to follow an elementary course based on the earlier book by Hunter Rouse, *Elementary Mechanics of Fluids*. This means that the reader is assumed to have already an understanding of some of the elementary principles of the subject, at about the level of a university graduate in civil or mechanical engineering. The mathematical knowledge required is also no higher than the level usually expected of an engineering graduate.

The first half of the book deals mainly with flow of an inviscid incompressible fluid. The general equations of motion are derived and methods of solving problems of irrotational flow are discussed. The treatment of conformal representation is particularly good; no previous knowledge is assumed and the subject is well explained. Aerofoil theory is considered only briefly.

The second half of the book deals with viscous flow, boundary layers and turbulence. In the chapter on turbulence there is a good explanation of some of the theoretical approaches that have been used, but in the limited space available it has not been possible to discuss theoretical or experimental results in any detail. The chapter on boundary layers can only be regarded as an introduction to the subject; the equations are derived and the main features of the flow are discussed, but there are only brief references to methods of calculation.

There are, of course, unavoidable difficulties in choosing the subject matter for a single volume on fluid mechanics at any level above an elementary one. Any attempt to cover the whole field would reduce the book to a collection of data, with no real explanation. The editor has wisely avoided this, and has been content to omit some important branches of fluid mechanics. For the aeronautical engineer the most notable omission is the whole subject of compressible fluid flow. Readers with practical interests outside aeronautics will also notice omissions; for example there is no mention of cavitation and only a brief reference to surface waves.

The aim of the book is to give an account of the principles of fluid mechanics and not to describe engineering applications. Because of the rather arbitrary choice of subject matter it cannot be recommended as a reference book, either for the practising engineer or for the research worker, but it should be useful as a textbook for the student who is prepared to work through it systematically. It is not primarily a book for aeronautical engineers, but aeronautical students will find nearly all of it useful and interesting.—W. A. MAIR.

BASIC ELECTRICITY. *Van Valkenburgh, Nooger and Neville, New York and the Technical Press, London, 1959. Five Volumes at 12s. 6d. per volume. 574 pp. in all. Illustrated.*

These five volumes comprise a course in basic electricity beginning with first principles and ending with quite advanced applications of alternating current and a brief introduction to electronics. The latter is the subject of a second series of volumes soon to be published.

This course of electricity is an American idea, developed as a standard course of technician training for the U.S. Navy, and the English version has been adapted to English usage by an Electronics Training Investigation Team of the Royal Electrical and Mechanical Engineers with War Office approval.

Knowing little more about the subject than the wiring of a table lamp or of an electric model railway, the reviewer settled down to read the books exactly as they were meant to be read. Any opinion formed as a result of such study is therefore based on limited experience of the subject—the impression of the student rather than the master.

Textbooks vary in value to the individual student as widely as the approach to the subject by the authors. Some deal with the subject in great detail and yet somehow never seem to get down to its practical, day-to-day application. Books on elementary electricity and magnetism seem to suffer particularly from this failing—they do not always seem able to emerge from the laboratory and its air of strange experiments with, seemingly, no clear application of elementary principles to nasty live wires which bite if handled thoughtlessly.

The first two volumes, at least, of *Basic Electricity* do exactly what the novice wants. In these days, the novice's introduction to electricity begins perhaps at the age of two, when he finds he can switch on a light. At five, perhaps, he can change a lamp bulb. He knows it is dangerous but he learns how to protect himself. Years later, he has to go back to the beginning of it all and start again but then he has what is, in some ways, a disadvantage— a preconceived idea, probably wrong, on how and why it all works. It is this breakdown and clarification of ideas that is so difficult.

The authors of *Basic Electricity* have done a very remarkable job and deserve credit for a novel approach to electricity. The text is grown-up, even racy and extremely well written. The illustrations are admirable and are chiefly in strip cartoon style, particularly in the early volumes. Though designed for the classroom they are aimed at the adult brain and they will no doubt succeed as they deserve. They seem best suited to the student who has not tackled the subject before or who has forgotten most of what he learnt at school and who needs a thorough refresher course.

Seldom can a reviewer emerge from a set of new books having learnt so much to his advantage. It is a pity that they cost so much, but lavish illustrations have to be paid for.—A.S.C.L.

AIRLINE PRICE POLICY. *Paul W. Cherington. Bailey Bros. and Swinfen, London, 1959. 471 pp. 60s.*

Professor Cherington's study of American domestic airline pricing policies is as he says, topical in the United States, where the Civil Aeronautics Board is conducting a general passenger fare investigation. But his arguments and conclusions are also relevant to the current problems of British and Continental air transport. The gist of Professor Cherington's message is that airlines should pay more attention to the use of pricing policy. In the United States, as he points out, the C.A.B., has "largely left the initiative in the pricing area to the carriers"; and he concludes that "this area of freedom should be enlarged in the future and . . . the carriers should be encouraged to exercise it".

He considers that the airlines have shown too naïve an attitude to the use of price as a marketing weapon. He advocates a more methodical approach, based on modern market research methods, to discover the possibilities of increasing revenue by introducing new classes of fares—such as the coach class—or by changing the structure of fares—and here he suggests a careful re-examination of fares on short-range services. In criticising airlines for failing to make more use of pricing policy, Professor Cherington surprisingly fails to point out that in the 1930s, before the C.A.B. was established, the airlines used pricing policy much more freely than they have done in the period since the war, which he describes as that in which the airlines had first been in a position to vary their fares. Thus his arguments for the weakening of the C.A.B.'s influence over airline fares are not as strong as they might have been.

Despite this, Professor Cherington is arguing for airline pricing policies that would be revolutionary in Europe. His book should encourage European airlines to think again before they commit themselves to the formation of a monopoly when the common market makes possible a weakening of the nationalistic barriers to air transport that have prevented even the degree of competition that has existed in the United States. And those who wish to use this opportunity to give Europe its C.A.B. would be well advised to read this book's account of the opposition of the C.A.B. to the opening of the coach class air services—for pioneering which the irregular carriers incidentally deserve more credit than Professor Cherington gives them—before they decide that this is the type of bureaucratic body that they wish to see controlling the air transport industry.—DAVID SAWERS.

WAR AND PEACE IN THE SPACE AGE. *Lt. Gen. James Gavin. Hutchinson, London, 1959. 287 pp. 21s.*

Anybody seriously interested in the fate of mankind will learn something from reading this book. Written by an American Wartime paratroop general who held—as his

last serving appointment until he retired last year—the important post of Chief of Research and Development to the U.S. Army, it is obviously based on an up-to-date and unusually complete knowledge of those scientific and technical developments on which the destiny of all of us now so clearly depends. In dealing comprehensively with the latest methods of making war, General Gavin gives some new information which this reviewer has not seen published before but more important is the way in which he puts many, apparently isolated, items of previously-released information into perspective and relates them to one another.

Easy to read and obviously the work of an enthusiast for his subject, this book is not, however, well written. The first chapter—which is presumably intended as a "come-on" to the casual reader who first opens its pages—is almost hysterical in tone. It is not likely to encourage the serious reader nor does it give any indication of the carefully-reasoned arguments which are to follow. The next few chapters are mainly autobiographical and, although interesting, seem out of place in a book of this type.

The "meat" of what General Gavin has to say is contained in two long essays entitled "The Decade of Dilemma: 1945-1955" and "The Decade of Decision: 1955-1965". These provide a—to the layman—sometimes rather confusing picture of the military situation in the first post-war decade and that now evolving in the second ten-year period but one which is nevertheless more comprehensive and which provides a broader view of the whole intricate subject than anything this reviewer has read before.

Immediate reactions to this study can be summarised as follows:—

(*i*) The so-called strategic "Absolute Weapon"—which from about 1950 (when the Russians acquired nuclear weapons) became the "Great Deterrent" levelled from both sides of the fence—will clearly not now be deliberately used by either side. This weapon is so clumsy and has now become so overwhelmingly powerful that its use would be suicidal to mankind and particularly to the two Greatest Powers. Both sides will, and without international agreement obviously must, continue to maintain this threat in being—now with manned-bombers, later with ballistic missiles—but neither side intends to use it. If it were to be used, hundreds of millions of people in North America and the Euro-Asian land masses would be exterminated within a few days.

(*ii*) The only feasible wars for some time now and for as far ahead as we can see into the future have been and will continue to be "limited" in character. Tactical nuclear weapons—which are sufficiently small and "clean" to be usable—are beginning to be practical and will soon be technically and economically the best answer for this kind of fighting. This is clearly General Gavin's opinion but it is a pity he does not pay more attention to the basic problem of how an effective demarcation can be maintained in practice by both combatants, should they start using tactical nuclear weapons, between the use of weapons which are sufficiently small and clean to be "acceptable" and those which are progressively less so until uncontrolled nuclear warfare is upon us.

(*iii*) Space vehicles will gradually take over from aircraft many of their most important military and transport roles. General Gavin, like so many military men, is obviously completely sold on unmanned devices, whether missiles or reconnaissance drones. This reviewer must admit, however, that he is still not entirely convinced that there will not be a greater continuing requirement for manned-aircraft—which will, of course, by gradual evolution become manned-space vehicles—for offensive, defensive and reconnaissance purposes than the missiles enthusiasts would have us believe. The ballistic missile is but the forerunner of an entirely new type of vehicle, it will not always have to be unmanned. It will certainly have men in it if their physical presence should continue to offer advantages over automatics or remote control.

(*iv*) A proper understanding of the time-scale and evolutionary trends of new developments is absolutely fundamental to any discussion of where they are leading us. It is clear from the many examples he quotes from the remote and more immediate past, that General Gavin is extremely well-read in military history and has made a close study of the evolution of strategy and tactics. He obviously benefits greatly from this knowledge and uses it in many of his extrapolations into the future. However, having said this, one is left in some doubt about the clarity with which he sees the broad framework within which technical developments are taking place. He leaps from one new development to another with the greatest facility and discourses on their possibilities and immediate implications most fluently but one is left with a confused picture of the broad objectives of the military technical policy about which he is obviously so well-informed but which he says is already lagging behind that of the Soviet Union and will slip still further back unless the Americans devote a greater proportion of their national resources to armaments, improve their defence organisation and modify their policies in several important respects. It is to be hoped that this impression of confusion in technical policy-making results from defects or limitations—possibly deliberate for reasons of Security—in this particular exposition and not from any deficiencies in American defence policy as such. If it does not, then perhaps even more drastic changes than General Gavin advocates are urgently required to prevent the West being gradually overwhelmed.

(*v*) By far the most disturbing thing about this book, however, is its complete lack of a constructive policy for the future survival of the human race. General Gavin and no doubt most of his service colleagues in Washington probably think that this is not their concern and are convinced that, because the objective of Russian military philosophy is "We will bury you" ("you" being all non-Communists), no reconciliation between the United States and the Soviet Union is possible. He agrees that Total War is impractical, foresees continuing intermittent Limited Wars—in due course with tactical nuclear weapons—to contain the spread of World Communism, advocates that we prepare ourselves to spring to the effective aid of future "Hungarys" but he says absolutely nothing about how the world's ideological deadlock is to be resolved. The final summary: "A Strategy for Peace", whose title will momentarily raise readers' hopes, looks only to the restoration of the military strategic initiative to the West. This may be urgently necessary but it is certainly a disappointingly limited objective. As General Gavin says: "In the United States Army we are brought up to abhor the contamination of military battles with political objectives". He also implies that, in his view, this is not a satisfactory basis on which to conduct military affairs in the modern world. It is a pity that this excellent study of military policy could not also have been related to a more practical political objective than the indefinite perpetuation of today's international situation.—PETER W. BROOKS.

Additions to the Library

Aircraft Weight and Balance Control. Third Edition. Henri G. d'Estout. Aero Publishers, Inc., Los Angeles, 1959. 125 pp. Illustrated. 3·35 dollars. Revised and enlarged, this third edition covers general principles of Aircraft Weight and Balance Control, Basic Measurements and Computations, Weight Shifting and Alterations, Weighing and Loading Procedures for all types of aircraft.

Celestial Mechanics. E. Finlay-Freundlich. Pergamon Press, London. 1958. 150 pp. 50s. *To be reviewed.*

Channel Turbulent Flow of an Electrically Conducting Fluid in the Presence of a Magnetic Field. P. S. Lykoudis, Purdue University, 1959. 19 pp.

Famous Airliners. Derek Harvey. Cassell, London. 1959. Illustrated. 100 pp., 10s. 6d. (each number). No. 1, The Viscount; No. 2, The Britannia; No. 3, The Seven Seas; No. 4, The Comet. These four excellent little books are an admirable addition to the library of the younger student of modern commercial aircraft. Each contains 100 or so pages of reading matter which is well and informatively written giving a clear description of the development of each type under review. The illustrations, on good quality paper, are well chosen to illustrate points of design and, in the cases of the Comet and the Britannia particularly the history of the various troubles in their early development is well described and illustrated. The potted history of the DC-7C contains a résumé of the whole DC Series from the DC-1 onwards, and includes a comparative table of dimensions and performance which is most interesting. The technical matter is fairly elementary, but that does not prevent the books from being useful.

Fire Control Principles. Walter Wrigley and John Hovorka. McGraw-Hill, London. 1959. 133 pp. Illustrated. 77s. 6d. *To be reviewed.*

Helicopter Dynamics and Aerodynamics. P. R. Payne. Pitman, London. 1959. 442 pp. Illustrated. 84s. *To be reviewed.*

Impact of Air Power, The. Eugene M. Emme (*Editor*). D. Van Nostrand Co., London. 1959. 915 pp. 79s. *To be reviewed.*

Indian Skyways—Aviation Directory of Asia (including Australia and New Zealand). W/Cdr. R. Vaughan-Fowler (*Editor*). Aeronautical Publications of India. 1959. 370 pp. 20s. Although the pattern is much the same as a more familiar aeronautical directory, its content is different. Convenient thumb indexes cover subjects such as India, Tourist (short descriptions of Indian beauty centres), Near and Middle East (general aeronautical information), Far East, Australia and New Zealand, World Aeronautical Organisations (giving some unfamiliar bodies as well as the more familiar), Who's Who (a comparatively short section) and two indexes to classified subjects and advertisers. This, with the *Aeroplane Directory* and *World Aviation Directory*, should suffice until the Space Directory comes along.

Introduction to the Theory of Compressible Flow. Shih-I Pai. Van Nostrand, London. 1959. 398 pp. 73s. *To be reviewed.*

L'Aviazione Civile all'Assemblea Constituente e nel Parlametno del Dopoguerra. Centro per lo sviluppo dei trasporti aerei. C.S.T.A. 1959. 660 pp. **L'Avazione Civile nei Consessi Tecnici e nella Stampa del Dopoguerra.** 1958. 171 pp. Two volumes giving particulars and texts of post-war references to civil aviation.

Materials for Rockets and Missiles. Robert G. Rank and William F. Zimmerman. Macmillan, London. 1959. 124 pp. Illustrated. 31s. 6d. *To be reviewed.*

Metals for Supersonic Aircraft and Missiles. D. W. Grobecker (*Technical Editor*), American Society for Metals, Cleveland, Ohio. 1958. 432 pp. Illustrated. No price given. *To be reviewed.*

Message from the President of the United States transmitting the First Annual Report of the Nation's Activities and Accomplishments in the Aeronautics and Space Fields (U.S. Aeronautics and Space Activities, January 1 to December 31, 1958): U.S.G.P.O. (obtainable from H.M.S.O.): 25 pp. 1s. 5d. This report starts "The United States entered the age of space exploration on January 31 1958." It ends "The United States is aware of the magnitude of the challenge and aware that it must be fully met."

Modern Trends in Documentation. Dr. Martha Boaz (*Editor*). Pergamon, London. 103 pp. 35s. A symposium of the School of Library Science, Southern California University at which papers were read by authorities in the science of librarianship. To anyone used to placid browsing through the shelves of a library, this insight into the "behind the scenes" technique of information retrieval, the classification of literature and the rest of modern library science will come as something of a rude shock.

Navy Wings. U.S. Bureau of Naval Personnel. U.S.G.P.O. 1955. 216 pp. Illustrated. 11s. 3d. Written, apparently, for service personnel this book deals with the U.S. Navy's air branch's mission and history, its development, organisation and the training programme.

Nuclear Propulsion and Engineering for Engineers, Demetrios George Samaras, The Technical Chamber of Greece, 1959. 724 pp. Diagrams, charts, tables. *To be reviewed.*

On the flight path of a Hypervelocity Glider. A. Miele. Purdue University. 1959. 31 pp.

Physical Metallurgy of Magnesium and its Alloys, The. G. V. Raynor, Pergamon Press, London, 1959. 531 pp. Illustrated. 75s. *To be reviewed.*

Proceedings of the Third U.S. National Congress of Applied Mechanics. Edited by R. M. Haythornthwaite. Pergamon Press, 1958. 864 pp. Illustrated. 140s. The complete text of over 100 papers presented at the Congress, held at Brown University in June, 1958. There are four general lectures, by Biot, Dryden, Hoff and Reissner and the technical papers are in four sections: Dynamics, vibrations, elastic waves; elasticity, elastic structures; plasticity, viscoelastic flow, fracture; fluid flow, aerodynamics, heat transfer. Any discussion there may have been has been omitted, which is perhaps as well, considering the size of the volume.

Rocket Encyclopaedia Illustrated. John W. Herrick (*Chief Editor*). Aero Publishers, Los Angeles, 1959. 607 pp. Illustrated. 12·50 dollars. *To be reviewed.*

Seventh Symposium (International) on Combustion. The Combustion Institute. Butterworths, London. 1959. 959 pp. Illustrated. £11 4s. This 1,000-page volume is a record of the 124 papers, with discussions, of the Symposium held at London and Oxford from 28th August to 3rd September 1958. All the names well known in the combustion field are included among the authors and organisers. The subject grouping of the pages is as follows: mechanisms of combustion reactions; spectroscopy of flames; ionization in flames; structure and propagation of flames; ignition and limits of inflammability; interaction of flames and surfaces; turbulence in flames; combustion in practical flowing systems; detonation and its initiation; special fuels; instrumentation in combustion research. The volume has been attractively compiled and well printed.

Shock Tube Driver Techniques and Attenuation Measurements. C. E. Wittliff and Merle R. Wilson. Cornell Aero Lab., Buffalo. 1957. 34 pp., figs., refs., Report No. AD-1052-A-4 prepared under contract AF 18 (603)-10 in connection with the development of the

hypersonic shock tunnel at the Laboratory. Techniques and relative efficiency of different driver gases, with the resultant shock-wave attenuation are discussed, and a survey of theories on attenuation is included.

Silver Dart, The. H. Gordon Green. Brunswick Press. Fredericton, N.B. 1959. 208 pp. Illustrated. 4·95 dollars. *To be reviewed.*

Some Notes on Dynamics of Trajectories. Harold Klein. Douglas Aircraft Report SM 23288. 1959. 165 pp. Diagrams. Notes compiled for a lecture series to cover introductory aspects of orbital calculation and space flight.

Soviet Planet Into Space, Booklet No. 48, Soviet News, Soviet Booklets, 3 Rosary Gardens, S.W.7. 1959. 41 pp. Illustrated. 1s. A plain language booklet, profusely illustrated, "digesting" material provided by Russian scientists. Obtainable from the publishers.

Statistical Handbook of Civil Aviation. U.S. Civil Aeronautics Administration; U.S.G.P.O. (H.M.S.O.). 131 pp. 5s. An official annual publication, ". . . generally recognised as the standard summary of official statistical data on the status of civil aviation in the United States."

Theoretical Studies of Unsteady Transonic Flow. M. T. Landahl. Privately published. Stockholm. 1959. 12 pp. Figures. Incorporates the subject-matter of five reports of the Aeronautical Research Institute of Sweden (F.F.A.).

Transactions, Volume 80, 1958. American Society of Mechanical Engineers. 1959. For reference only. The position of the deposit libraries for these transactions has been under review and the Society must count itself fortunate that it appears to be still chosen. The volume is slightly over 3½ inches thick.

Two-Dimensional Oblique Shock Calculations in a Hypersonic Diffuser. T. Cheng, Purdue University. 1958. 25 pp.

Reports

AERODYNAMICS

BOUNDARY LAYER—*see also* FLUID DYNAMICS

The interaction between a weak normal shock wave and a turbulent boundary layer. G. E. Gadd. C.P. 424. 1959.—(1.1.3.3×1.2.2.2).

Boundary-layer-transition measurements on hemispheres of various surface roughnesses in a wind tunnel at Mach numbers from 2·48 to 3·55. A. Bandettini and W. E. Isler. N.A.S.A. Memo 12-25-58A *T.I.L.* 6277. *March* 1959.—(1.1.2.4).

The fluorescent-oil film method and other techniques for boundary-layer flow visualization. D. L. Loving and S. Katzoff. N.A.S.A. Memo. 3-17-59*L. T.I.L.* 6310. *March* 1959.—(1.1×1.12).

Space-time correlations and spectra of wall pressure in a turbulent boundary layer. W. W. Willmarth. N.A.S.A. Memo 3-17-59*W. T.I.L.* 6317. *March* 1959.
Measurements are described which provide additional information about the structure of the turbulent boundary layer; they are applicable to the problems of boundary layer induced noise inside an aeroplane fuselage and to the generation of waves on water.—(1.1.3.1.)

An investigation of the effect of a highly favorable pressure gradient on boundary-layer transition as caused by various types of roughnesses on a 10-foot-diameter hemisphere at subsonic speeds. J. B. Peterson and E. A. Horton. N.A.S.A. Memo. 2-8-59*L. T.I.L.* 6321. *April* 1959.—(1.1.2.1).

Blowing-type boundary-layer control as applied to the trailing-edge flaps of a 35° swept-wing airplane. M. W. Kelly et al. N.A.C.A. Report 1369. 1958.—(1.1.6.1×1.8.2.2×1.3.4).

COMPRESSIBLE FLOW—*see also* BOUNDARY LAYER
THERMO-AERODYNAMICS
AIRCRAFT OPERATION
ELECTRONICS

The flow upstream of finite span spoilers at supersonic speeds. A. Stanbrook. C.P. 427. 1959.—(1.2.3.1).

The calculation of interference drag between wing lift and fuselage thickness at supersonic speeds. E. W. Graham and R. M. Licher. Douglas Report S.M.-23446. *Feb.* 1959.—(1.2.3.1×1.10.1.2).

The effect of moment-of-area-rule modifications on the drag, lift, and pitching-moment characteristics of an unswept aspect-ratio-6 wing and body combination. R. R. Dickey. N.A.S.A. Memo. 2-24-59*A. T.I.L.* 6300. *March* 1959.—(1.2.2.1).

Numerical solution of the flow of a perfect gas over a circular cylinder at infinite Mach number. F. M. Hamaker. N.A.S.A. Memo. 2-25-59*A. T.I.L.* 6301. *March* 1959.—(1.2.3.1).

Several methods for reducing the drag of transport configurations at high subsonic speeds. R. T. Whitcomb and A. R. Heath. N.A.S.A. Memo. 2-25-59L. *T.I.L.* 6314. *March* 1959.
The methods include a wing leading-edge extension, a fuselage addition, and additions on the wing. Results are presented for a complete, improved transport configuration which incorporates the fuselage and wing additions.—(1.2.1×1.10.2.2).

A numerical method for calculating the wave drag of a configuration from the second derivative of the area distribution of a series of equivalent bodies of revolution. L. L. Levy and K. K. Yoshikawa. N.A.S.A. Memo. 1-16-59*A. T.I.L.* 6324. *April* 1959.—(1.2.3.1).

Investigation of some wake vortex characteristics of an inclined ogive-cylinder body at Mach number 2. L. H. Jorgensen and E. W. Perkins. N.A.C.A. Report 1371. 1958.—(1.2.3×1.4.3).

CONTROLS—*see also* BOUNDARY LAYER

An investigation of the performance of various reaction control devices. P. A. Hunter. N.A.S.A. Memo. 2-11-59*L. T.I.L.* 6289. *March* 1959.—(1.3.6).

Wind-tunnel investigation of a small-scale sweptback-wing jet-transport model equipped with an external-flow jet-augmented double slotted flap. J. L. Johnson. N.A.S.A. Memo. 3-8-59*L. T.I.L.* 6328. *April* 1959.—(1.3.4).

FLUID DYNAMICS—*see also* COMPRESSIBLE FLOW

Wall turbulence. C. Ferrari. N.A.S.A. R.E. 2-8-59*W. T.I.L. RPN*6. *March* 1959.
A theoretical study has been made of the factors affecting the development of a turbulent flow in the presence of a solid wall, "wall turbulence." The basic set of governing relationships are not sufficient in themselves to provide the solution to the turbulent flow problems, but when used with certain simplifying assumptions they permit a careful study of some simple cases of wall turbulence, such as a flat plate with or without a uniform pressure gradient or flow in a uniform channel. A brief discussion of other works which may lead to a sound rational basis for future work on wall turbulence is included.—(1.4.2).

Some basic aspects of magnetohydrodynamic boundary-layer flows. R. V. Hess. N.A.S.A. Memo. 4-9-59*L. T.I.L.* 6322. *April* 1959.—(1.4.4×1.1).

LOADS—*see also* STABILITY AND CONTROL

Evaluation of several approximate methods for calculating the symmetrical bending-moment response of flexible airplanes to isotropic atmospheric turbulence. F. V. Bennett and R. T.

Yntema. N.A.S.A. Memo. 2-18-59*L. T.I.L.* 6311. *March* 1959.
Two modal methods, the mode-displacement and force-summation methods, and a matrix method (segmented wing method) are studied.—(1.6.3×2×33.1).

STABILITY AND CONTROL—*see also* BOUNDARY LAYER
AIRCRAFT OPERATION
MISSILES

Some effects of yaw damping on airplane motions and vertical-tail loads in turbulent air. J. Funk and T. V. Cooney. N.A.S.A. Memo. 2-17-59*L. T.I.L.* 6281. March 1959.—(1.8.1.1×1.6.3).

Effect of horizontal-tail chord on the calculated subsonic span loads and stability derivatives of isolated unswept tail assemblies in sideslip and steady roll. K. W. Booth. N.A.S.A. Memo. 4-1-59*L. T.I.L.* 6304. *March* 1959.—(1.8.1.2).

THERMO-AERODYNAMICS—*see also* TESTING AND INSTRUMENTS

Experimental investigation of aerodynamic effects of external combustion in airstream below two-dimensional supersonic wing at Mach 2·5 *and* 3·0. *R. G. Dorsch et al. N.A.S.A. Memo.* 1-11-59*E T.I.L.* 6278. *March* 1959.—(1.9×34.1.1).

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The range covered includes the hovering condition as well as two forward-flight conditions. Comparisons are also included between experimental and calculated blade stiffnesses and natural frequencies.—(1.11.3×33.1.2).

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See also STRUCTURES—LOADS

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The effect of lift-drag ratio and speed on the ability to position a gliding aircraft for a landing on a 5,000*-foot runway. J. P. Reeder. N.A.S.A. Memo.* 3-12-59*L. T.I.L.* 6329. *April* 1959.
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See MECHANICAL ENGINEERING
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See also STRUCTURES—THEORY AND ANALYSIS

Performance of two boron-modified S-816 alloys in a turbo-jet engine operated at 1650°F. W. J. Waters et al. N.A.S.A. Memo. 3-3-59*E. T.I.L.* 6283. *March* 1959.
Stress rupture tests at 1650°F and tensile and impact tests at both 1650°F and room temperature were made.—(21.2.2).

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Preliminary study of a piston pump for cryogenic fluids. A. E. Biermann and R. C. Kohl. N.A.S.A. Memo. 3-6-59*E. T.I.L.* 6285. *March* 1959.
Preliminary performance data are presented for a low-speed, five-cylinder piston pump designed to handle boiling hydrogen. The pump is designed to deliver 55 gall./min. at a discharge pressure of 135 lb./in.^{2} The design pump speed is 240 r.p.m. —(23×18.2).

MISSILES

A 20,000*-kilowatt nuclear turboelectric power supply for manned space vehicles. R. E. English et al. N.A.S.A. Memo.* 2-20-59*E. T.I.L.* 6279. *March* 1959.—(25×27.3×27.6).

The effects of target and missile characteristics on theoretical minimum miss distance for a beam-rider guidance system in the presence of noise. E. C. Stewart et al. N.A.S.A. Memo. 2-12-59*A. T.I.L.* 6299. *March* 1959.
The factors considered were missile natural frequencies and damping ratios, missile steady state acceleration capabilities; target evasive manoeuvre characteristics, and angular scintillation noise. Applications are given.—(25.1).

The synthesis of optimum homing missile guidance systems with statistical inputs. E. C. Stewart and G. L. Smith. N.A.S.A. Memo. 2-13-59*A. T.I.L.* 6325. *April* 1959.
The factors considered are: target evasive manoeuvre, radar glint noise, missile manoeuvrability, and the inherent time-varying character of the kinematics.—(25.1).

Study of the oscillatory motion of manned vehicles entering the Earth's atmosphere. S. C. Sommer and M. Tobak. N.A.S.A. Memo 3-2-59*A. T.I.L.* 6318. *April* 1959.
Expressions for the oscillatory motion are derived as continuous functions of the properties of the trajectory. Results are applied to a study of the oscillatory behaviour of re-entry vehicles which have decelerations that remain within limits of human tolerance.—(25.2×1.8.2.1).

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A five-stage solid-fuel sounding-rocket system. A. G. Swanson. N.A.S.A. Memo. 3-6-59*L. T.I.L.* 6307. *March* 1959.
A description is presented of a rocket system which can boost payloads of 25 and 100 lb. to altitudes of 525 and 300 n.m. respectively.—(25.3).

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Theory of the double-gyroscopic vertical. A. Y. Ishlinski. N.A.S.A. R.E. 3-10-59*W. T.I.L. RPN* 5. *March* 1959.
Theoretical error corrections are developed, and a short analysis of the stability of the system is presented. In addition, it is shown that, with the aid of a simple computer, geocentric latitude may be obtained.—(26×18).

POWER PLANTS

See also MATERIALS
MISSILES

Investigation of a 4·5*-inch-mean-diameter two-stage axial-flow turbine suitable for auxiliary power drives. R. Y. Wong and D. E. Monroe. N.A.S.A. Memo.* 4-6-59*E. T.I.L.* 6302. *March* 1959.
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Aerodynamic characteristics in the approach, superfine and negative pitch ranges of two four-bladed propellers with N.A.C.A. series 16 *blade sections. A report of tests carried out jointly by the staffs of de Havilland Propellers, and Rotol Ltd. R. & M.* 3105, 1959.—(29.1).

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*Contribution a l'étude des ultrasons aériens: production et applications. R. Boucher. Pubs. Sc. et Tech. N.T.*79. 1958. (*In French*).
The relationship between aerodynamic configuration and acoustic emission for various supersonic air jets is considered and suggestions for how acoustic methods may be used to disperse certain artificial fogs and industrial aerosols are made. —(32.2.3).

STRUCTURES

LOADS *see also* AERODYNAMICS—LOADS
HELICOPTER AERODYNAMICS

Study of taxiing problems associated with runway roughness. B. Milwitzky. N.A.S.A. Memo. 2-21-59*L. T.I.L.* 6312. *March* 1959.—(33.1.2×33.2.3.5×5×6).

THEORY AND ANALYSIS *see also* MATHEMATICS
LOADS

Theoretical determination of lifetime of compressed plates at elevated temperatures. G. Herrmann and H-N. Chu. N.A.S.A. Memo. 2-24-58*W. T.I.L.* 6316. *March* 1959
Theoretically predicted lifetimes of 2024-T3 aluminium alloy plates at 450°F are compared with experimental values obtained previously.—(33.2.4.5.9×21.2).

STRUCTURAL ELEMENTS

Compression tests on circular cylinders stiffened longitudinally by closely spaced Z-section stringers. J. P. Peterson and M. B. Dow. N.A.S.A. Memo. 2-12-59*L. T.I.L.* 6308. *March* 1959.
The results are presented and compared with available theoretical results for the buckling of orthotropic cylinders.—(33.4.3.1).

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See also AERODYNAMICS—THERMODYNAMICS

Untersuchungen des Temperaturganges innerhalb von Bordgeräten und ihren Bauteilen. O. Weber. D.F.L.-Bericht 107. 1959. (*In German*)—(34).

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